This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

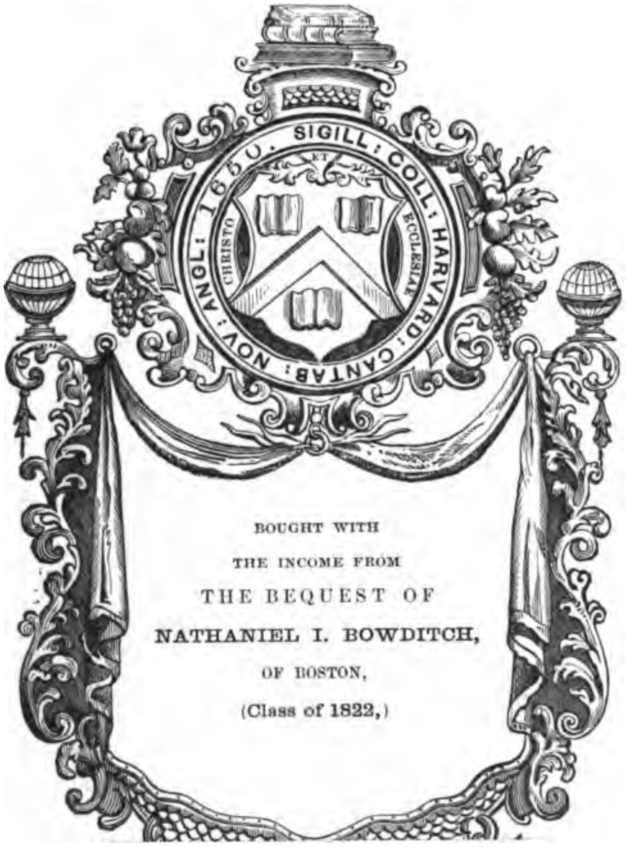
About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Math
5709.03

TEXT

Math 5709.03


NOV: ANGL: 1650. SIGILL: COLL: HARVARD: CANTAB:
CHRISTO ET ECCLESIAE

BOUGHT WITH
THE INCOME FROM
THE BEQUEST OF
NATHANIEL I. BOWDITCH,
OF BOSTON,
(Class of 1822,)

SCIENCE CENTER LIBRARY

315
1401

DESCRIPTIVE GEOMETRY;

WITH NUMEROUS PROBLEMS
AND PRACTICAL APPLICATIONS

BY

WILLIAM S. HALL, C.E., E.M., M.S.,
PROFESSOR OF GRAPHICS AND MINING IN LAFAYETTE COLLEGE, EASTON, PA.

WITH A QUARTO ATLAS OF 18 PLATES

NEW YORK
D. VAN NOSTRAND COMPANY
23 MURRAY AND 27 WARREN STS.
1903

Math 5709.03

HARVARD COLLEGE
SEP 10 1903
LIBRARY.

Bowditch Fund
(Text + Atlas.)

COPYRIGHT, 1902, BY
D. VAN NOSTRAND COMPANY

TYPOGRAPHY BY C. J. PETERS & SON
BOSTON, MASS., U. S. A.

PREFACE

THE text books on Descriptive Geometry, with very few exceptions, deal only with first angle projection. But in the best recent practice in mechanical drawing, the third angle is used. The third angle is also commonly employed in perspective. It would seem to be desirable, then, not to confine the student exclusively to the use of any one angle. In this book all four angles are used. Thus the problems become general, and a large variety of constructions may be introduced under each problem.

By having the problems for construction put in a separate volume, and by having several modifications under each problem, blackboard work can be readily assigned to the members of a class in recitation, and no two students need be given exactly the same work.

If the student is required to be prepared to make the construction for each problem under all possible conditions, a thorough understanding of the problem is necessary.

A large number of carefully arranged problems and some practical applications are given.

The first few problems on the point, line, and plane are fully analyzed. Then follows a list of problems left to the student for solution. In the part of the book devoted to curves and curved surfaces, more problems are analyzed and fewer are left to the student to solve without assistance.

The importance of the study of Descriptive Geometry, both for mental discipline and on account of its industrial utility, is very ably set forth in two quotations that are given at the end of the introductory chapter.

I desire to take this opportunity of acknowledging my indebtedness to my former teacher, the late Prof. J. M. Silliman, who, for a number of years, gave an excellent course in Descriptive Geometry in Lafayette College.

WM. S. HALL.

EASTON, PA.

CONTENTS.

CHAPTER I.

FIRST PRINCIPLES.

PAGE

1. Definitions 1
2. Projections of a Point 1
3. Revolution of Vertical Plane 2
4. Projections of a Line 3
5. Representation of Planes 4
6. Notation and Conventions 5
7. Profile Planes 7

CHAPTER II.

PROBLEMS ON THE POINT, LINE AND PLANE.

8. Traces of a Line 9
9. Length of a Line 10
10. Points and Lines in Oblique Planes 10
11. Revolution of Points and Lines 11
12. Plane Angles 14
13. Planes 16
14. Additional Problems for Construction 24

CHAPTER III.

CURVES AND TANGENTS TO CURVES.

15. Generation and Classification of Lines 29
16. Curves and Tangents 30

CHAPTER IV.

SURFACES.

17. Generation and Classification of Surfaces 40
18. Single Curved Surfaces and Tangent Planes 41
19. Surfaces of Revolution 47
20. Intersections and Developments 51
21. Warped Surfaces 59
22. Additional Problems on Surfaces 67

DESCRIPTIVE GEOMETRY

CHAPTER I.

FIRST PRINCIPLES

Art. 1. Definition.

1. Descriptive Geometry treats of the representation of geometrical magnitudes by drawings upon plane surfaces and the graphical solution of problems relating to these magnitudes.

Two coördinate planes are commonly employed. In orthographic projections these coördinate planes are perpendicular to each other, and one is usually assumed to be a horizontal plane. The line of intersection of these planes is called the Ground Line. The four diedral angles are distinguished by numbers. In Fig. 1, H represents the horizontal plane, V the vertical plane, and GL is the ground line. H_1 is that part of the horizontal plane in front of the vertical plane, H_2 is that part of H behind V, V_1 is that part of the vertical plane above the horizontal plane, and V_2 is that part of V below H.

Representing the 1st, 2d, 3d, and 4th angles by I, II, III, and IV respectively:

I is between H_1 and V_1.
II " " V_1 " H_2.
III " " H_2 " V_2.
IV " " V_2 " H_1.

Art. 2. Projections of a Point.

2. The planes H and V are called planes of projection. The horizontal projection of a point is the point in which a line from

the given point perpendicular to *H* intersects *H*. The vertical projection of a point is the point in which a line through the given point perpendicular to *V* intersects *V*. Lines projecting points on *H* are called *H*-projecting lines, and lines projecting points on *V* are called *V*-projecting lines. In Fig. I, a_1^h is the horizontal projection of a_1, and a_1' is its vertical projection. $a_1 a_1^h$ and $a_1 a_1'$ are the projecting lines of a_1. If a plane be passed through these projecting lines it will be perpendicular to *H*, *V* and *GL*. This plane intersects *H* and *V* in the lines oa_1^h and oa_1' perpendicular to *GL* at the same point *o*. Hence oa_1 is a rectangle, and $oa_1^h = a_1' a_1$ and $oa_1' = a_1^h a_1$; *therefore the distance from the horizontal projection of a point to GL is equal to the distance from the point to the V plane, and the distance from the vertical projection to GL is equal to the distance from the point to the horizontal plane.*

The two projections of a point determine the position of the point in space; for the point a_1 is contained in the line through a_1^h perpendicular to *H*, and also in the line through a_1' perpendicular to *V*, therefore it is the point of intersection of these two lines.

a_2^h and a_2' are the projections of a point a_2 in *II*.
a_3^h " a_3' " " " " " a_3 " *III*.
a_4^h " a_4' " " " " " a_4 " *IV*.

If a point be situated in either coördinate plane it will be its own projection on that plane, and the other projection will be in *GL*.

Art. 3. Revolution of Vertical Plane.

3. In order that both projections of an object may appear on the same plane surface, the *V* plane is revolved about *GL* until it coincides with *H*; thus as seen in Fig. 2, the *V* plane revolves about *GL* in the direction shown by the arrows until it coincides with *H*. In this rotation the vertical projection a_1' describes the arc of a vertical circle, $a_1'a_1^v$, whose center is at o_1 and after revolution, the vertical projection appears at a_1^v. But

$o_1a_1^v = a_1a_1^h$, therefore, the distance from the revolved position of the vertical projection of a point to *GL* is equal to the distance from the point to *H*. And as $o_1a_1^v$ is evidently in the same straight line with $o_1a_1^h$, it follows that after the revolution of *V*, the two projections of a point are in the same perpendicular to *GL*. Likewise, after the revolution of *V*, the two projections of a point a_2 in the second angle are a_2^h and a_2^v, and the two projections of a point a_3 in the third angle are a_3^h and a_3^v.

After the revolution of *V*, the two planes of projection coincide, and taking the plane of the paper on which the drawing is made to represent the coincident planes, the projections of the points shown in Fig. 2 will appear as in Fig. 3. Examination of Figs. 2 and 3 will show that the two projections of points in the four angles are situated with reference to *GL* as follows:

	Hor. Proj.	Ver. Proj.
1st Ang.	below	above
2d Ang.	above	above
3d Ang.	above	below
4th Ang.	below	below

Thus it will be seen that any two points in the same perpendicular to *GL* may be taken as the projections of a point in space. Hence, if a point in space is to be shown by two orthographic projections, a horizontal line is first drawn for the *GL*. Then an indefinite perpendicular to *GL* is drawn, and distances along this line are laid off equal to the distances from the point in space to the planes of projection above or below *GL* according to the given table.

Art. 4. Projections of a Line.

4. The projection of a line upon a plane is the line which contains the projections of every point of the given line. In Fig. 4, the horizontal projection of the line *ab* is determined by the lines which project its points on *H*, and as these lie in a plane aba^hb^h perpendicular to *H*, the horizontal projection is evidently $a^h b^h$. Similarly, a plane through the line *ab*, perpendicular to *V*, intersects *V* in a line $a'b'$, which is the vertical projection of *ab*. After the revolution of *V*, the vertical projection is shown at $a^v b^v$.

A plane passed through a line perpendicular to *H* will be called the *H*-projecting plane. Likewise a plane through the line perpendicular to *V* will be called the *V*-projecting plane.

Either projection of a line is determined in position when the projections of two points of the line on the assumed plane are known. As in Fig. 4, the horizontal projection of the line *ab* is determined when the horizontal projections of two points *a* and *b* are found; then the horizontal projection is the line connecting a^h and b^h.

If through each projection of a line a plane is passed perpendicular to the corresponding plane of projection, each plane will contain the given line in space, and the line is determined by the intersection of the planes. Therefore, any two rectilinear projections can be the projections of one and but one line in space. In Fig. 5, lines *M*, *N*, *O* and *L* are situated in the first, second, third and fourth angles respectively.

Thus it will be seen that any two lines in a drawing intercepted between two perpendiculars to *GL* may be taken as the projections of some line in space.

PROB. 1. To draw the projections of a point in any angle, at given distances from the planes of projection.

PROB. 2. To draw the projections of a line in any angle, the ends of the line being at given distances from the planes of projection.

PROB. 3. To draw the projections of lines that are parallel and perpendicular to the planes of projection.

Art. 5. Representation of Planes.

5. If a given plane is not parallel to either of the planes of projection it will intersect them in lines which meet at *GL*. The intersection of the plane with *H* is called the ***horizontal***

trace of the plane, and its intersection with V is called the *vertical trace*. As two intersecting lines determine a plane, any plane is determined by its traces. In Fig. 6, the plane MON intersects H in the horizontal trace HP, and intersects V in the vertical trace P'. After the revolution of V, the vertical trace is shown at VP. The two traces intersect at the point O in GL. After the revolution of V the plane MON is represented as in Fig. 7 by the traces HP and VP. The traces of the same plane in the second angle are H_2P and VP, in the third angle H_2P and V_2P, and in the fourth angle, HP and V_2P. In Fig. 7, Q is a plane perpendicular to H and oblique to V, R is a plane perpendicular to V and oblique to H, S is a plane perpendicular to both H and V, and T is a plane parallel to GL.

There are eight different positions which planes have with reference to H and V, as follows:

1. Obl. to H, Obl. to V.
2. Per. to H, Obl. to V.
3. Obl. to H, Per. to V.
4. Per. to H, Per. to V.
5. Per. to H, Par. to V.
6. Par. to H, Per. to V.
7. Par. to GL.
8. Passing through GL.

Prob. 4. To construct the traces of planes in the different diedral angles when the planes make given angles with the planes of projection.

Art. 6. Notation and Conventions.

6. A point in space is designated by a small letter, and its horizontal and vertical projections by the same letter with h or v respectively written above; as in Fig 4, a is a point in space, and a^h and a^v are its projections.

A line in space is designated by a capital letter, and its horizontal and vertical projections by the same letter with h or v

written above, as in Fig. 4, the line ab is denoted by M, and its projections by M^h and M^v.

A plane is designated by a capital letter. Its traces are distinguished by prefixing H or V to this letter. As seen in Figs. 6 and 7, the plane MON is denoted by P, and its traces by HP and VP. If the plane is determined by two intersecting lines, as A and B, it will be denoted by (A, B). Similarly, (A, b) denotes the plane determined by the line A and the point b, and (a, b, c) denotes the plane determined by the three points.

The point at which the eye is situated is called the point of sight. If the lines projecting an object on a plane are perpendicular to that plane the projection is called orthographic. These lines being parallel to each other will intersect at an infinite distance. These projecting lines may be regarded as visual rays, and if the eye is supposed to be placed in a perpendicular line to the plane and at an infinite distance in front of it, the projection will appear from the point of sight to resemble exactly the object it represents. The point of sight is usually taken in the first angle, and objects in this angle are then visible, while objects in the other angles are regarded as concealed by the planes of projection.

Lines that are given or required in any construction are shown as full lines when visible, and as broken lines (lines made of short dashes) when concealed.

Auxiliary lines or lines of construction are shown as broken lines when visible or concealed.

Visible traces of planes, given or required, are shown as full lines. When the traces are invisible, or when the planes are auxiliary, the traces are shown as broken and dotted lines, as H_2P and V_2P in Fig. 7.

The two projections of a point are connected by a dotted line.

A plane or line is called oblique when it is oblique to both planes of projection.

In Descriptive Geometry, lines and surfaces are regarded as indefinite in extent unless limited portions are specified.

When the word *line* is used, a right line will be meant.

When reference is made to two projections or traces, it will be understood that the one first mentioned is the horizontal one, unless the contrary is stated.

Art. 7. Profile Planes.

7. A profile plane is a plane perpendicular to both planes of projection. In Fig. 8, plane P is a profile plane. The projection a_1, of the point a on the profile plane, is the intersection with the plane of a perpendicular through a to the plane. The profile plane is then revolved about its intersection with V until it concides with V, and the profile projection then appears at a_2. After V revolves into H, the profile projection appears at a^p. Denoting the intersection of the profile plane with H by $G_1\ L_1$, the distance from a^p to $G_1\ L_1$ is seen to be equal to the distance from the point a to V.

"The study of Descriptive Geometry possesses an important philosophical peculiarity, quite independent of its high industrial utility. This is the advantage which it so preëminently offers in habituating the mind to consider very complicated geometrical combinations in space, and to follow with precision their continual correspondence with the figures which are actually traced — of thus exercising to the utmost, in the most certain and precise manner, that important faculty of the human mind which is called 'imagination,' and which consists, in its elementary and positive acceptation, in picturing to ourselves, clearly and easily, a large and variable collection of ideal objects, as if they were really before us. . . . While it belongs to the geometry of the ancients by the character of its solutions, on the other hand it approaches the geometry of the moderns by the nature of the questions which compose it. These questions are in fact eminently remarkable for that generality which constitutes the true fundamental character of modern geometry; for the methods used are always conceived as applicable to any figures whatever, the peculiarty of each having only a purely secondary influence."

AUGUST CONTE: *Cours de Philosophie Positive.*

"A mathematical problem may usually be attacked by what is termed in military parlance the method of 'systematic approach'; that is to say, its solution may be gradually felt for, even though the successive steps leading to that solution cannot be clearly foreseen. But a Descriptive Geometry problem must be seen through and through before it can be attempted. The entire scope of its conditions, as well as each step toward its solution, must be grasped by the imagination. It must be 'taken by assault.'"

GEORGE SYDENHAM CLARKE, *Captain Royal Engineers.*

8. TABLE OF ABBREVIATIONS AND CONVENTIONS.

H	Horizontal plane of projection.
V	Vertical plane of projection.
P	Profile plane of projection.
H_1	Horizontal plane of projection in front of V.
V_1	Vertical plane of projection above H.
H_2	Horizontal plane of projection back of V.
V_2	Vertical plane of projection below H.
GL	Ground line.
$a, b, c,$ *etc.*	Given points.
$e, f, g,$ *etc.*	Required points.
$k, l, m, n, o,$ *etc.*	Auxiliary points.
$M, N, O,$ *etc.*	Given lines.
$S, T, W,$ *etc.*	Required lines.
$G, H, I, J,$ *etc.*	Auxiliary lines.
$Q, R, L,$ *etc.*	Given planes.
$X, Y, Z,$ *etc.*	Required planes.
$D, H, C,$ *etc.*	Auxiliary planes.
HP	Horizontal trace of plane P.
VP	Vertical trace of plane P.
I., II., III., IV.	Diedral angles between H and V.
r *and* l	Refer to the angles which projections of lines or traces of planes make with GL. For instance, (45°—r) indicates a line drawn from GL toward the right making an angle of 45° with GL.
$a_1, a_2\ a_3,$ *etc.*	Successive positions of point a. Likewise, successive positions of lines will be denoted by numerical subscripts.
′ *and* ″	Placed to the right and above a number indicate feet and inches respectively.
h	Designates a horizontal projection when written above and to the right of another letter (as an exponent).
v	Designates a vertical projection when written above and to the right of another letter (as an exponent).
(G, I)	Plane of the lines G and I.
In	Inaccessible distance.
∞	Infinite distance.
Par.	Parallel.
Per.	Perpendicular.
Hor.	Horizontal.
Ver.	Vertical.
Obl.	Oblique.
M_{ht}	Horizonal trace of line M.
M_{vt}	Vertical trace of line M.

CHAPTER II.

PROBLEMS ON THE POINT, LINE AND PLANE.

Art 8. Traces of a Line.

9. THE horizontal trace of a line is the point in which it intersects *H*, and the vertical trace of a line is the point in which it intersects *V*.

PROB. 5. Given the projections of a line to find its traces.

Analysis. To find the horizontal trace. The horizontal trace being in *H*, is vertically projected in *GL*. Since every point of a line is vertically projected in the vertical projection of the line, the vertical projection of the horizontal trace is at the intersection of *GL* and the vertical projection of the line. The horizontal trace of the given line is its own horizontal projection, and it must be in a perpendicular to *GL* through its vertical projection, and also in the horizontal projection of the given line; therefore, the horizontal projection of the horizontal trace is the intersection of the horizontal projection of the line, and a perpendicular to *GL* through its vertical projection.

The analysis for finding the vertical trace will be obtained by substituting *H* for *V*, *V* for *H*, horizontal for vertical, and vertical for horizontal, in the above analysis for the horizontal trace.

In Figs. 9 and 10 the line *ab* is given.

The horizontal trace e^h is found by continuing the vertical projection $a'b'$ in Fig. 9 until it intersects *GL* at e^v, and erecting a perpendicular to *GL* at e^v until it intersects the horizontal projection a^hb^h at e^h. The vertical trace f^v is found by continuing the horizontal projection a^hb^h until it intersects *GL* at f^h, and erecting a perpendicular to *GL* at f^h until it intersects the vertical projection at f^v. After the revolution of V into H, the construction is shown as in Fig. 10, $a'b'$ taking the position a^vb^v.

PROB. 6. Given the traces of a line to find its projections.

This problem is the converse of Prob. 5.

Art. 9. Length of a Line.

10. PROB. 7. To find the length of a line joining two given points.

Analysis. As the line connecting the two points contains them, the projections of the line must contain the projections of the points. Hence, the horizontal projection of the given line is the line connecting the horizontal projections of the given points, and the vertical projection of the given line is the line connecting the vertical projections of the given points. If the trapezoid formed by the given line, the H-projecting lines of two of its points and the horizontal projection of the given line, be revolved about the horizontal projection of the given line until it coincides with H, the revolved position of the given line will show the line in its true length.

In Fig. 11, the given points are a and b, the horizontal projection of the line joining the points is a^hb^h, and the vertical projection of the line joining the points is $a'b'$. The trapezoid aa_hb_hb is revolved about a_hb_h until it lies in H, when ab is seen at a_1b_1, which gives the true length of the line. After the revolution of V, the construction is shown in Fig. 12. a^ha_1 is perpendicular to a^hb^h and equal to a_0a^v, and b^hb_1 is perpendicular to a^hb^h and equal to b_0b^v.

If in this analysis horizontal be substituted for vertical, and *vice versa*, and V be put for H, the true length of the line will be found by revolution about the vertical projection into V, as seen in the line a_2b_2.

Art. 10. Points and Lines in Oblique Planes.

11. PROB. 8. If a line is situated in a given oblique plane, and one of its projections is given, to find the other projection.

Analysis. When the horizontal projection is given. If a line lies in a plane, the traces of the line must be in the traces of the plane. Then the horizontal trace of the line, being in the horizontal projection of the line and in the horizontal trace of the plane, must be the intersection of these lines. Likewise, the vertical trace of the line is the intersection of the vertical trace of the plane and the vertical projection of the line.

Each trace of the line is its own projection in the plane in which it lies, and its other projection is in *GL*. Thus two points of the required projection are found, and joining them gives the required projection. In Fig. 13, the horizontal projection M_h of a line lying in the plane *Q* is given to find its vertical projection. The intersection of *HQ* and M^h, M_{ht}^h, is the horizontal trace of the line *M*, which is vertically projected at M_{ht}^v. The intersection of M^h and *GL* is M_{vt}^h, the horizontal projection of the vertical trace. The vertical trace must lie in a perpendicular to *GL* at M_{vt}^h, and also in *VQ*, therefore at their intersection, M_{vt}^v. M^v, the required vertical projection, connects M_{ht}^v and M_{vt}^v.

Prob. 9. If a point is situated in a given plane and one of its projections is given, to find the other projection.

Analysis. Any line drawn through the given projection of the point in the corresponding plane of projection may be taken as one projection of a line lying in the plane and containing the point. The other projection of this line is found by Prob. 8. Then the required projection of the point will be the intersection of a perpendicular to *GL* through the given projection of the point with the projection of the line just found.

Art. 11. Revolution of Points and Lines.

12. Prob. 10. To find the angle which a given line makes with either of the planes of projection.

Analysis. To find the angle which a line makes with *H*. Pass a line through one point of the given line perpendicular to *H*, and revolve the given line about this line until it becomes parallel to V. Then the vertical projection of the line after revolution makes an angle with GL equal to the required angle.

In Fig. 14, let M be the given line, and L, perpendicular to H through one end of the line, is taken as the axis. In this revolution the point b describes the arc of a horizontal circle whose center is in L. The horizontal projection of this arc will be an equal arc through b^h having its center at a^h; and as this arc is in a horizontal plane through b, its vertical projection will be a straight line through b^v parallel to GL.

The given line after revolution is parallel to V, hence the horizontal projection M_1^h is parallel to GL. The horizontal projection of the end b after revolution will be in M_1^h and in $b^hb_1^h$, therefore at their intersection b_1^h. The vertical projection of the end b after revolution will be in $b_1^vb^v$, and in a perpendicular to GL through b_1^h, therefore at b_1^v. The point a being in the axis does not change its position. Therefore b_1^v and a^v are two points in the vertical projection of the line after revolution, giving M_1^v. The angle $ma^vb_1^v$ is the required angle.

PROB. 11. A point is assumed in a given plane, and it is required to find the position of the point after the plane has been revolved about one of its traces into the corresponding plane of projection.

Analysis. When the plane is revolved about its horizontal trace into H.

The point will move in a circular arc in a plane perpendicular to the horizontal trace, and after revolution will be found in a line through its horizontal projection perpendicular to the trace. In the revolution the distance from the point to the axis does not change, and will be equal to the hypothenuse of a right triangle, one side of which is equal to the distance from the horizontal projection of the point to the axis, and the other side is equal to the distance from the point in space to H.

In Fig. 15, let Q be the plane, and a a point in the plane. As the point moves in an arc in a plane perpendicular to HQ, it is horizontally projected in a^ha_1 perpendicular to HQ. A right triangle is constructed with perpendicular sides equal to a^hm

and a^vn, and thé hypothenuse is the distance from m to the required point a_1.

PROB. 12. To revolve a given point through a given angle about an axis perpendicular to one of the planes of projection.

Analysis. When the axis is perpendicular to V. The point describes in the revolution an arc of a circle lying in plane parallel to V. The vertical projection of the arc is an equal arc having the vertical projection of the axis for its center. The horizontal projection of the arc is a straight line parallel to GL.

In Fig. 16, let a be the point, M the axis, and @ the angle of revolution. With M^v as a center, and M^va^v as a radius, describe an indefinite arc $a^va_1^v$, which will be the vertical projection of the arc of revolution. Taking the angle $a^vM^va_1^v$ equal to @ determines a_1^v, the vertical projection of the point after revolution. The horizontal projection of the point after revolution must be in a line parallel to GL through a^h, and also in a perpendicular to GL through a_1^v, therefore at their intersection a_1^h.

PROB. 13. To revolve a given line through a given angle about an axis perpendicular to one of the planes of a projection.

Analysis. Any two points of the line are revolved about the axis through the given angle as in Prob. 12. The line connecting the revolved positions of these points will be the revolved position of the given line.

PROB. 14. To cause a given line by two successive revolutions to become perpendicular to one of the planes of projection.

Analysis. To bring the line perpendicular to H. The line is first revolved until it is parallel to V, as in Prob. 10. Then an axis, through the stationary point of the line perpendicular to V, is assumed, and the line is revolved about this axis until it becomes perpendicular to H.

In Fig. 17, M is the given line. By Prob. 10, the line is revolved about (a^h, O^v) as an axis until it becomes parallel to V at M_1. Then the line M_1 is revolved about (N^h, a^v) as an axis. The extremity b_1 describes an arc parallel to V, whose vertical projection is an arc passing through b_1^v and having a^v as its center. When the line becomes perpendicular to H, its vertical projection will coincide with O^v, and the vertical projection of the revolved position of b_1 will be at b_2^v. The horizontal projection of the arc described by b_1 will be $b_1^h a^h$, and the horizontal projection of M_1 after revolution will be the point a^h.

Art. 12. Plane Angles.

13. If two lines intersect they have a point in common. The horizontal projection of this common point must be in the horizontal projections of both lines, hence at their intersection. Likewise, the vertical projection of the intersection of the two lines must be the intersection of the vertical projections of the two lines. And as the two projections of a point must be in a perpendicular to *GL*, the line joining the intersections of the corresponding projections of the lines must be in a perpendicular to *GL*. Hence the projections of two intersecting lines may be assumed by taking at pleasure both projections of one line, and the horizontal projection of the other line; then through the point of intersection of the assumed horizontal projections, a line is drawn perpendicular to *GL*, intersecting the vertical projection of the first line, and through this point of intersection any line may be drawn to represent the vertical projection of the second line.

PROB. 15. Given two intersecting lines, to find the traces of the plane passing through them.

Analysis. The horizontal traces of the lines must be in the horizontal trace of the plane, and the vertical traces of the lines must lie in the vertical trace of the plane. Therefore the line connecting the horizontal traces of the given lines will be the horizontal trace of the plane, and the line connecting the vertical traces of the given lines will be the vertical trace of the plane.

In Fig. 18, the lines *M* and *N* are given intersecting at the point *o*. The horizontal traces of *M* and *N* are respectively M_{ht} and N_{ht}; then the line *HX* connecting them will be the required horizontal trace. The vertical traces of *M* and *N* are M_{vt} and N_{vt} respectively, and the connecting line *VX* will be the vertical trace. The two traces intersect on *GL*.

Prob. 16. To construct the traces of a plane containing three given points.

Analysis. By connecting one of the points with the other two by lines, two intersecting lines are obtained which determine the plane of the three given points. Then the traces are found as in Prob. 15.

Prob. 17. To find the angle between two intersecting lines.

Analysis. One of the traces of the plane of the two lines is first found. If the plane be revolved about its horizontal trace into H, or about its vertical trace into V, the angle between the lines in their revolved positions will be the required angle.

In Fig. 19, the given lines are M and N intersecting at o. The horizontal trace of the plane of the two lines is HD. By Prob. 11, the resolved position of o is o_1. The point M_{ht} is in the axis, hence its position does not change; then M_1^h is the revolved position of M. Similarly, N_1^h is the revolved position of N. Therefore the angle at o_1 is the required angle.

Prob. 18. To construct the projections of a line bisecting the angle between two lines.

Analysis. The angle between the two given lines is found in its revolved position as in Prob. 17. This angle is then bisected by a line, and the projections of this bisecting line are found after the plane of the given lines is revolved back to its original position.

Prob. 19. To construct the projections of a line to make given angles with the planes of projection.

Analysis. The projections of a line of definite length, which makes the given angle with H and is parallel to V, are drawn. Through the projections of one end of the line just assumed, the projections of another line of equal length, making the given angle with V and parallel to H, are drawn. The first line is revolved about a vertical axis passing through its intersection with the second line, and the second line is revolved about an axis perpendicular to V through the same point. When these two rotating lines coincide, a line is found which makes the required angle with each plane of projection.

In Fig. 20, the line M is assumed. M^h being parallel to GL and M^v making the same angle with GL which the required line is to make with H. Then the line N is assumed, N^v being parallel to GL and N^h making the same angle with GL which the required line is to make with V. M^v must be equal to N^h, as lines M and N are to be equal in length. The line M is revolved about L, a vertical line through the point m. In this revolution, the point a describes a horizontal arc, which is horizontally projected in a^hf^h and vertically projected in a^vf. The line N is revolved about O, an axis perpendicular to V through the point m. In this revolution, the end b describes an arc parallel to V, which is horizontally projected in b^hf^h and vertically projected in b^vf^v. When the lines M and N meet, the extremities of the two lines must coincide, and f the point of intersection of the two arcs must be a point of the required line. The point m, being stationary, is another point of the required line. Therefore S, the line connecting m and f, is the required line.

Art. 13. Planes.

14. A horizontal line lying in a plane may be called a ***horizontal of the plane.***

The vertical projection of a horizontal line is parallel to GL; hence in Fig. 21, if M is a horizontal of the plane Q, M^v is parallel to GL. The line M must be parallel to HQ as it is in the plane Q and also parallel to H; therefore M^h must be parallel to HQ. The vertical trace of the line M is evidently M_{vt}.

If a line is perpendicular to a plane, each projection of it will be perpendicular to the corresponding trace of the plane. For the H-projecting plane of the line is perpendicular to the given plane and also to H, hence it is perpendicular to the horizontal trace of the given plane; therefore, the horizontal trace of the given plane being perpendicular to the projecting plane is perpendicular to every line in it, and therefore perpendicular to the horizontal projection of the given line. Similarly, it may be proved that the vertical projection of the line is perpendicular to the vertical trace of the plane.

PROB. 20. To find the line of intersection of two planes.

Case I. When the vertical traces and also the horizontal traces intersect within the limits of the drawing.

Analysis. The planes intersect in a line. Since the line of intersection is contained in each plane, its horizontal trace must be in the horizontal trace of each plane, or at the intersection of the horizontal traces of the two planes. Likewise, the vertical trace of the line of intersection must be at the intersection of the vertical traces of the two planes. The traces of the line being two points of the line, by connecting them the line of intersection is obtained.

In Fig. 22, the line of intersection of the given planes Q and R is S. The horizontal trace of S is S_{ht}, the intersection of the horizontal traces of the two planes, and is vertically projected at S^{v}_{ht} in GL. The vertical trace of S is S_{vt}, the intersection of VQ and VR, and is horizontally projected in GL at S_{vt}^{h}. The line S connects its two traces.

Case II. When the horizontal or vertical traces do not intersect within the limits of the drawing.

Analysis. Let it be assumed that the horizontal traces do not intersect. If it is assumed that the vertical traces intersect at an accessible distance, one point of the line of intersection is known at once. To obtain another point an auxiliary horizontal plane may be passed cutting both of the given planes. The lines of intersection of this plane with the given planes will meet in a point common to the two planes.

In Fig. 23, the vertical traces of the given planes Q and R meet in the point S_{vt} giving one point of the line of intersection. The auxiliary horizontal plane D cuts from the planes Q and R the horizontals H and L respectively. The intersection f of these horizontals is a point in the required line. The line S, connecting f and S_{vt}, is the required line.

PROB. 21. To find the point in which a given line intersects a given plane.

Analysis. If any plane be passed through the given line it will intersect the given plane in a line containing the required point. The required point being a point of the given line, and also a point of the line of intersection of the two planes, it must be the intersection of the given line with the line of intersection of the two planes.

In Fig. 24, P is the given plane, and M the line. The auxiliary plane passed through the line M is the H-projecting plane of M, its vertical trace being VD. The intersection of the planes D and P is the line whose vertical projection is H^v. The lines M and H intersect in the required point f.

PROB. 22. To find the length of a given line intercepted between two given planes.

PROB. 23. To find the perpendicular distance from a given point to a given plane.

Analysis. The projections of the perpendicular from the point to the plane will pass through the projections of the point. The horizontal projection of the perpendicular will be perpendicular to the horizontal trace of the plane, and its vertical projection will be perpendicular to the vertical trace of the plane. The point in which this perpendicular intersects the plane is found by Prob. 21. The required length is the distance from the given point to the foot of the perpendicular in the plane, and may be found by Prob. 7.

In Fig. 26, the given plane is Q and the given point is a. I^h and I^v are the projections of the perpendicular from a to the plane. This perpendicular intersects the plane at the point o. When the line I is revolved about its horizontal projection into H it appears at I_1, whose length from a_1 to o_1 is the required distance.

PROB. 24. To project a given line on a given plane.

Analysis. From any two points of the line perpendiculars are drawn to the plane, and the line connecting the points in which these perpendiculars intersect the plane is the required projection.

In Fig. 27, Q is the given plane and M is the given line.

From two points of the line as a and b, perpendiculars L and K are drawn to the plane, and the points a_1 and b_1 in which the perpendiculars cut the plane are found. The line M_1 connecting these points is the required line.

PROB. 25. To pass a plane through a given point parallel to a given plane.

Analysis. The corresponding traces of parallel planes are parallel. The projections of a horizontal of the required plane through the given point can be drawn, for its horizontal projection will be parallel to the horizontal trace of the given plane, and its vertical projection will be parallel to GL. The vertical trace of this horizontal will be one point in the vertical trace of the required plane. Through the vertical trace of this horizontal, the vertical trace of the required plane is drawn parallel to the vertical trace of the given plane, and through the point where the required vertical trace meets GL, the horizontal trace is drawn parallel to the given horizontal trace.

In Fig. 28, Q is the given plane and a is the given point. L^h is drawn through a^h parallel to HQ, and L^v is drawn through a^v parallel to GL. L is a horizontal of the required plane, and its vertical trace is L_{vt}. VX is drawn through L_{vt} parallel to VQ, and HX is drawn through d parallel to HQ. X is the required plane.

PROB. 26. To pass a plane through a given point perpendicular to a given line.

Analysis. As the plane is to be perpendicular to the line, the traces of the plane must be perpendicular to the projections of the line. The projections of a horizontal of the required plane through the given point may be drawn; the horizontal projection of this line will be perpendicular to the horizontal projection of the given line, and its vertical projection will be parallel to GL. The vertical trace of the required plane is drawn through the vertical trace of the horizontal of the plane and perpendicular to the vertical projection of the given line. The horizontal trace of the required plane is then drawn perpendicular to the horizontal projection of the given line.

In Fig. 29, M is the given line, and a is the given point. L^h is drawn through a^h perpendicular to M^h, and L^v is drawn through a^v parallel to GL. L is a horizontal of the required plane, and its vertical trace is L_{vt}. VX is drawn through L_{vt} perpendicular to M^v, and HX is drawn through d perpendicular to M^h, and X is the required plane.

PROB. 27. To pass a plane through a given line perpendicular to a given plane.

Analysis. From any point of the given line a perpendicular is drawn to the given plane. This perpendicular and the given line determine a plane perpendicular to the given plane.

In Fig. 30, Q is the given plane, and M is the given line. Through any point of M as o a line L is drawn perpendicular to the plane Q. The plane X of the intersecting lines M and L is the required plane.

PROB. 28. To pass a plane through a given point and parallel to two given lines.

Analysis. Draw a line through the point parallel to each given line. The plane of these lines will be the required plane.

In Fig. 31, M and N are the given lines, and a is the given point. If two lines are parallel, their corresponding projections are parallel. Through a^h, M_1^h and N_1^h are drawn parallel to M^h and N^h respectively; and through a^v, M_1^v and N_1^v are drawn parallel to M^v and N^v respectively. The plane X of the lines M_1 and N_1 is the required plane.

PROB. 29. To pass a plane through a given line parallel to another given line.

Analysis. Through any point of the first line a line is drawn parallel to the second line. The plane of these intersecting lines is the required plane.

PROB. 30. To find the angles which a given plane makes with the planes of projection.

Analysis. To find the angle which a given plane makes with H, an auxiliary plane is passed perpendicular to the horizontal trace of the given plane. This auxiliary plane will intersect the given plane and H, in lines which will make with each other the plane angle which measures the required diedral angle. To find the angle which the given plane makes with *V*, an auxiliary plane perpendicular to the vertical trace is constructed.

In Fig. 32, *Q* is the given plane. *D* is an auxiliary plane, perpendicular to the horizontal trace. *HD* is perpendicular to *HQ*, and as *D* is a vertical plane, *VD* will be perpendicular to *GL*. The vertical projection of the intersection of *D* and *Q* is L^v. The angle which the line *L* makes with its own horizontal projection is the measure of the angle between *Q* and *H*. The true size of this angle may be shown by revolving the *H*-projecting plane of the line *L* about its horizontal trace into *H*, giving the required angle $n^h m^h n'$.

PROB. 31. In Fig. 32, to find the angle which plane *Q* makes with profile plane *P*.

PROB. 32. Given the traces of a plane, to find the true size of the angle between the traces.

PROB. 33. Given one trace of a plane and the angle between the traces, to construct the other trace.

PROB. 34. A corner of a cube is truncated by a plane which makes given angles with two faces. What angle does it make with the third face?

PROB. 35. To construct the traces of a plane that shall make given angles with the two planes of projection.

Analysis. Assume that the required plane makes angles α and β with *H* and *V* respectively. If through any point of *GL* planes be passed perpendicular to the two traces of a given plane, these planes will intersect in a line perpendicular to the given plane. By Prob. 30, each of these auxiliary planes cuts the given plane in a line, which makes with one of the planes of projection the angle which the given plane makes with that plane of projection. If each of these auxiliary planes be revolved into a plane of projection about that trace which is perpendicular to *GL*, the intersection of the auxiliary planes will appear in its true size in each revolved position, and each revolved position of this line will be perpendicular to the revolved position of the intersection of one of the auxiliary planes with the given plane.

In Fig. 33, with any point *o* of *GL* as center, and with any length *ox* as radius, for the perpendicular distance to the required plane, describe a semicircle. Then a line *mn*, making the angle α with *GL*, and tangent to this arc will be the revolved position of the intersection of the plane through *o* perpendicular to the horizontal trace; likewise, a line making the angle β with *GL* and tangent to the same arc, will be the revolved position of the intersection of the plane through *o* perpendicular to the vertical trace, giving *rs*. In the counter-revolution of the line *rs*, the point *r* must describe an arc *rt*, to which the required vertical trace is tangent. But *n* is a point of the vertical trace; therefore the line *nX* tangent to the arc *rt* is the required vertical trace. Similarly, *sX* tangent to the arc *mv* described by the point *m* in the counter-revolution of *mn*, is the required horizontal trace.

PROB. 36. To locate a point on a given plane at given distances from the two planes of projection.

PROB. 37. To find the shortest distance from a given point to a given line.

Analysis. A perpendicular drawn from the given point to the given line will be the required shortest distance. The length of this perpendicular may be found by passing a plane through the given point and line, and revolving this plane about one of its traces into the corresponding plane of projection. A line drawn through the revolved position of the point perpendicular to the revolved position of the line will be the required distance.

In Fig. 34, *M* is the given line, and *a* is the given point. Through *a* and *M* a plane is passed whose horizontal trace is *HT*. When this plane is revolved about *HT* into *H*, the point *a* revolves to a_1 and the line *M* revolves to M_1. The line *S* through a_1, perpendicular to M_1, is the required distance.

PROB. 38. To find the angle which a given line makes with a given plane.

Analysis. The angle made by a line with a plane is the same as the angle made by the line with its projection on the plane. If the line be continued until it intersects the given plane, and if another point of the line be projected on the plane, a right triangle will be formed by the given line, its projection, and the line projecting the point. In this right triangle, the angle between the given line and the line projecting one of its points, will be the complement of the required angle. In Fig. 35, M is the given line, and P is the given plane. Through a point a of the line, a perpendicular H is drawn to the plane. HD is the horizontal trace of the plane of the lines M and H. Revolving this plane about its horizontal trace into H, the lines M and H are shown at M_1 and H_1, and the angle between M_1 and H_1 is the complement of the required angle.

PROB. 39. To find the angle between two given planes.

Analysis. If a plane be passed perpendicular to the intersection of the given planes, it will be perpendicular to both planes, and will cut lines from these planes that will make with each other an angle which measures the required diedral angle.

In Fig. 36, R and Q are the given planes, and H is their line of intersection. HD is the horizontal trace of a plane perpendicular to line H. The plane D cuts from R a line whose horizontal trace is r^h, and a line from Q, whose horizontal trace is s^h. If the H-projecting plane of the line H be revolved about its vertical trace into V, H_1 is the revolved position of H. If through m_1, the revolved position of m, a line m_1n_1 be drawn perpendicular to H_1, it will be the revolved position of a perpendicular to line H, lying in plane D. If now the plane D be revolved about HD into H, the intersection of the lines cut from R and Q by D will revolve to o in H^h, at a distance from HD equal to m_1n_1. or^h and os^h are, therefore, the revolved positions of the lines cut from R and Q by the plane D, and the angle between them is the measure of the required angle.

PROB. 40. To find the perpendicular distance between two lines not in the same plane.

Analysis. Through one of the lines a plane is passed parallel to the other line, and the second line is projected on this plane. At the point where this projection intersects the first line, a line is drawn perpendicular to the plane. This line will both intersect and be perpendicular to the given lines, and the required distance is the length along this line between the given lines.

In Fig. 37, M and N are the given lines. Through any point of M, as c, a line is passed parallel to N; then the plane of this line L and the line M is parallel to N. Through any point of N as r a perpendicular is dropped to plane D, the plane of M and L. The intersection of this perpendicular H with plane D, or s, is then found. A line I drawn through s parallel to N will be the projection of N on plane D. At the point o, where lines M and I intersect, the line J is erected perpendicular to plane D. The line J will intersect the line N in the point e, and oe is the required line whose true length may now be found.

Art. 14. Additional Problems for Construction.

15. PROB. 41. A square building is covered by a hip roof. If the hip rafter makes an angle of 30° with H, what angle does the roof make with H?

PROB. 42. Having given one projection of a line, to construct the other projection; the line to pass through a given point, and to make a given angle with H or V.

PROB. 43. Fig. 38 represents a cube, with holes drilled at a and b perpendicular to the faces, with depths of 1″ and ¾″ respectively. At what point of the top and at what angle must a hole be started to join the ends of the given holes.

PROB. 44. To revolve a plane through a given angle about an axis perpendicular to one of the planes of projection.

PROB. 45. To find where a line intersects a plane determined by two intersecting lines without finding the traces of the plane of the lines.

PROB. 46. To find the intersection of a plane and a polyedron.

PROB. 47. To find the angle between a diagonal of a cube and one of the edges which it cuts.

PROB. 48. To draw the projections of a regular polygon situated in a given oblique plane.

PROB. 49. To find the projections of a given regular pyramid with its base in a plane that is given.

PROB. 50. Through a point in a line which lies in a given plane, to draw a line which shall lie in the given plane and make a given angle with the given line.

PROB. 51. To find the point of a given plane which is at given distances from the traces.

PROB. 52. Through a given point in a given plane to construct a line which shall lie in the given plane and make a given angle with one of the planes of projection.

PROB. 53. Through a given point not in a given plane to construct a line which shall be parallel to the plane and make a given angle with one of the planes of projection.

PROB. 54. Through a given point in a plane which makes given angles with the planes of projection, to pass a line lying in the plane and making given angles with the two planes of projection.

PROB. 55. Two parallel horizontal shafts are inclined at 30° to a vertical wall. The first shaft is 4′ above, and the second shaft is 5′ below a floor, and the distance between the centers of the shafts is 15′. An 8′ pulley on the first shaft just clears the wall by 6″, and drives a 5′ pulley on the second shaft on the opposite side of the wall by an 18″ belt. Show where the wall and the floor must be cut for the belt. [Scale, $\frac{1}{2}''=1'$.]

PROB. 56. To pass a plane through a point and a line and revolve the plane about one of its traces into *H* or *V*, finding the revolved positions of the point and line.

PROB. 57. To pass a plane through two parallel lines and revolve the plane about one of its traces into *H* or *V*, finding the revolved positions of the lines.

PROB. 58. Given one trace of a plane and also the projections of one point in the plane, to construct the other trace.

PROB. 59. Given one trace of a plane and the angle between the two traces, to find the other trace.

PROB. 60. If the traces of a plane are given and the revolved position of a point of the plane when the plane has been revolved about one of its traces into *H* or *V*, to find the projections of the point.

Prob. 61. Given the angle between the traces of a plane, one point in the horizontal trace and the angle which the plane makes with *H*, to construct the traces.

Prob. 62. The lengths of the traces of a plane on *H*, *V* and *P* included between the planes are 2″, 2½″ and 3″ respectively. What angles does this plane make with *H*, *V* and *P*?

Prob. 63. To construct a line through a given point and parallel to two given planes.

Prob. 64. To construct a line which shall be parallel to a given line and shall intersect two other lines not in the same plane.

Prob. 65. To find the point of intersection of three given planes.

Prob. 66. In Fig. 39, a ray of light from *a* is reflected from *V* at *b* to the profile plane *P*, and thence to *H*. Find the points where the reflected ray meets *H* and *P*, and the angles which it makes with *H* and *P*.

Prob. 67. To cause a given oblique plane by two revolutions to become parallel to another given plane.

Prob. 68. A right pyramid has for its base an equilateral triangle of 3″ on a side. What is the altitude of the pyramid if the diedral angles between its faces are 60°?

Prob. 69. To construct a line that shall be parallel to and lie at a given distance from a given plane and that shall also intersect two given lines.

Prob. 70. To find the perpendicular distance between two given parallel planes.

Prob. 71. To construct a line at given distances from two given planes.

Prob. 72. To find the point that is at given distances from three given planes.

Prob. 73. To find a plane passing through a given line and at a certain distance from a given point.

Prob. 74. Through a given point to pass a plane making a certain angle with a given line.

Prob. 75. Through a given point to draw a line that shall be at given distances from two given lines.

Prob. 76. To find the point that is equidistant from four given points.

Prob. 77. To pass a plane through a given line and equidistant from two given points.

Prob. 78. To pass a plane through a given point parallel to a given line and perpendicular to a given plane.

Prob. 79. To erect a perpendicular to a given plane that shall intersect two given lines.

Prob. 80. To find a point in a given line that is at a given distance from a given point.

Prob. 81. Given one projection of a point lying at a given distance from a given line, to find the other projection of the point.

Prob. 82. To cause a given oblique plane by two revolutions to make given angles with *H* and *V*, and to find the revolved position of a polygon lying in the given plane.

Prob. 83. To draw a line through a given point that shall intersect a given line, and shall make a given angle with a given plane.

Prob. 84. Given the line of intersection of two planes, the angle between them, and also a point in a trace of one of the planes, to determine the planes.

Prob. 85. To determine the plane bisecting the angle between two given planes.

Prob. 86. To construct a plane through a given line making a given angle with a given plane.

Prob. 87. To find the point of a given line that is equidistant from two given planes.

Prob. 88. To pass a plane through a given line that shall make a given angle with a given plane.

Prob. 89. To determine a plane that shall lie at given distances from three given points.

Prob. 90. To determine a plane perpendicular to one plane of projection and at a given angle with a given line.

Prob. 91. To pass a plane equidistant from two given lines.

Prob. 92. Through a given point to construct a line at a given distance from another point and that shall intersect a given line.

Prob. 93. To find the shortest line that can be drawn parallel to a given plane and terminating in two given lines.

Prob. 94. To determine a plane that shall contain a given line; this line making a given angle with one of the traces of the plane.

CHAPTER III.

CURVES AND TANGENTS TO CURVES.

Art. 15. Generation and Classification of Lines.

16. Every line may be generated by the motion of a point. An *element* of a line is an infinitely short line connecting two consecutive points of the line. The moving point which generates the line is called the *generatrix*. The nature of the line is determined by the law that directs the motion of the generatrix.

Lines may be divided into three classes: 1st, RIGHT LINES, which are generated by a point moving always in the same direction. 2d, PLANE CURVES, which are generated by a point moving in a plane, the direction of its motion continually changing. 3d, CURVES OF DOUBLE CURVATURE, which are generated by a point moving so that no four consecutive points lie in the same plane.

17. A right line is tangent to a curve when it contains two consecutive points of the curve. In Fig. 40, let L be a right line through any two points, as a and b, of the curve C. If the line L be revolved about one of these points as a, the second point of intersection b will gradually approach a. When these points of intersection become consecutive the secant L takes the position of T, and is tangent to the curve at the point a.

Two curves are tangent to each other at a common point, when they may have the same line tangent to each of them at the common point.

If two curves are tangent to each other, their projections on the same plane will be tangent.

18. A normal to a curve at any point is the perpendicular to the tangent to the curve at the point of tangency.

19. Some of the important plane curves are the circle, parabola, ellipse, hyperbola, cycloid, epicycloid, hypocycloid, involute of a circle, conchoid of Nicomedes, logarithmic spiral, spiral of Archimedes, sinusoid, and Schiele's anti-friction curve.

Art. 16. Curves and Tangents.

20. The *parabola* may be generated by a point moving in a plane, so that at any time its distance from a given point called the *focus*, is equal to its distance from a given line called the *directrix*.

PROB. 95. Given the focus and directrix of a parabola, to construct the curve by points, and to draw a tangent to the curve at a point on the curve.

In Fig. 41, let f be the focus and D the directrix. A line drawn through f, perpendicular to D, is called the axis of the curve. To find a point of the curve, draw a perpendicular ap to the axis at any point a, then with f as a center and oa as a radius describe an arc, cutting ap in p. By construction, the point p is equally distant from the point f and the line D, and therefore is by definition a point of the parabola. Similarly, any number of points may be found.

To construct a tangent to the parabola at a point c, a perpendicular to the axis is let fall at c. Then the distance vm from the vertex to the foot of the perpendicular is measured, and an equal distance is laid off on the axis produced from v to t. The required tangent joins the points t and c. (For proof, see "Analytical Geometry.")

21. The *ellipse* may be generated by a point moving in a plane, so that the sum of its distances from two given points, called foci, shall always be equal to a given line.

PROB. 96. Given the foci of an ellipse and the sum of the distances from the foci to a point on the curve, to construct the ellipse by points, and to draw a tangent to the curve at any point.

In Fig. 42, let f and f' be the foci, and vv' the sum of the focal distances to any point of the curve. With either focus as *f* as center and any distance *va*, greater than *vf* and less than *vv′*, as radius, describe an arc. Then with *f′* as center, and *v′a* as radius, describe another arc cutting the first one in *p*. The sum of the distances from *p* to the foci will be equal to the given line *vv′*, and therefore *p* is a point of the ellipse. Similarly, any number of points may be found.

To draw a tangent to the ellipse at a point *c*, a circle circumscribing the ellipse is first drawn, and the perpendicular from *c* to *vv′* is extended to intersect the circle at *c′*. A tangent to the circle at *c′* is then drawn, cutting *vv′* produced at *t*. *tc* will be the required tangent. (For proof, see "Analytical Geometry.")

The shortest and longest lines which can be inscribed in an ellipse are called conjugate axis and transverse axis respectively. The axes are perpendicular to each other.

Prob. 97. Given the two axes of an ellipse, to construct the curve by concentric circles on the axes, and to draw a tangent from a point without the curve.

In Fig. 43, the axes *rr′* and *vv′* bisecting each other at *o* are given. Then circles are drawn on the axes as diameters. A radius *oc* is drawn to any point *c* of the outer circle, and a perpendicular *cm* is let fall from *c* to *vv′*. At the point *c′*, the extremity of radius *oc′*, a line *c′p* is drawn parallel to *vv′*. *p*, the intersection of *cm* and *c′p*, is a point of the ellipse. Similarly, any number of points may be found.

To draw a tangent to the ellipse from any exterior point, as *t*. First, with *r* as a center and the semi-transverse axis as a radius, an arc is drawn which will intersect the transverse axis in the foci *f* and *f′*. With either focus as *f* as center and with a radius equal to the transverse axis, describe an arc *ln*; then with *t* as center and its distance from the other focus *f′* as radius, describe an arc intersecting the arc *ln* in *l* and *n*. By joining the points *l* and *n* with *f*, lines are obtained which intersect the ellipse in *x* and *y*, the points of tangency. *tx* and *ty* will be required tangents.

(For proof, see "Analytical Geometry.")

22. The *hyperbola* may be generated by a point moving in a plane, so that the difference between its distances from two given points called foci is equal to a given line.

PROB. 98. Given the foci and the transverse axis of an hyperbola to construct the curve by points and to draw a tangent to the curve at any point.

In Fig. 44, let f and f' be the foci and vv' the transverse axis. With either focus as f for a center, and with any radius as fp greater than fv', describe the arc pp'. Then with the other focus f' as center with a radius equal to $fp—vv'$, describe an arc cutting the first arc in p. p is a point of the hyperbola, because the difference between its distances from the foci is equal to a constant distance vv'. Similarly, any number of points in the right branch may be constructed. The left branch is drawn in the same manner.

To draw a tangent to the hyperbola at any point as c, the focal lines fc and $f'c$ are drawn. The tangent ct bisects the angle fcf'. (For proof, see "Analytical Geometry.")

"The hyperbola of most frequent occurrence in the arts is the equilateral, or rectangular hyperbola. It is called equilateral because its axes are equal, and rectangular because its asymptotes are perpendicular. It may be constructed as in Prob. 98 by taking the foci distant from the center of the transverse axis by a length equal to the hypothenuse of a right triangle whose perpendicular sides are the equal semi-axes. In mechanical engineering the curve is commonly constructed as in Fig. 45. OX and OY are perpendicular lines, and a is a given point on the curve. ae is drawn parallel to OX, and through a and any other point as e on ae, perpendiculars af and en are drawn to OX. Then line Oe is drawn intersecting af in l. The line mp through l parallel to OX intersects en in p, which is a point of the required curve. Similarly, any number of points may be found.

23. The cycloid, epicycloid, hypocycloid, and involute are called trochoids.

These curves are proper curves for the teeth in wheel gearing.

24. The common *cycloid* is a plane curve generated by a point in the circumference of a circle as the circle rolls along a right line.

PROB. 99. To construct the common cycloid and to draw a tangent to the curve at any point.

In Fig. 46, let *obd* be the rolling circle, *ox* the right line on which it rolls, and *o* the generating point. To find a point on the cycloid, draw a line *fg* parallel to *ox*, cutting the circle in any point *g*. Then on a line through the center *r*, parallel to *ox*, lay off *rl* equal to arc *og* rectified. Now with *l* as a center, and with a radius equal to the radius of the given circle, draw an arc cutting *fg* in *p*. *p* will be a point of the cycloid, for the point *g* will be in contact with the line *ox* when the center of the rolling circle is at *l*, and the generating point *o* will then have risen just as far as *g* has fallen. Similarly, any number of points on the cycloid may be found.

An approximate rectification of the arc of a circle along a tangent to the arc at one extremity may be readily made as in Fig. 47. Let *r* be the center of a circular arc *oa* which is to be rectified along the tangent *ot*. The chord *oa* is bisected at *c* and produced until *od* = *oc*. Then with *d* as a center, and *da* as radius, an arc is described cutting *ot* in *b*, and *ob* is the required rectification. If the arc is less than 60°, the approximation is very close, and the error diminishes rapidly as the arc becomes smaller.

To draw a tangent to the cycloid at any point as *a*. When the generating point is at *a*, the center of the rolling circle is at *h*. At this instant every point in the circle is rotating about *m*, which is therefore called the *instantaneous center*; *ma* will then be normal to the curve at *a*, and a perpendicular *at* to this normal will be the required tangent.

The cycloid is known as the curve of quickest descent; i.e., if two points along a right line inclined to the vertical be connected by different curves, a weight will slide from the upper point to the lower one more quickly along the cycloid than along any other curve.

25. An *epicycloid* is a plane curve generated by a point in the circumference of a circle which rolls upon another circle with which it is tangent externally.

Prob. 100. To construct an epicycloid and a tangent to the curve.

In Fig. 48, *R* and *r* are the centers of the fixed and rolling circles respectively, and *o* is the generating point. With *R* as a center, describe an arc *pg*, cutting the rolling circle in any point as *g*. Then the arc *og* is developed on the fixed circle from *o* to g'. The radius Rg' is continued to intersect the circle described by the center of the rolling circle at *l*. Now with *l* as a center, and with a radius equal to the radius of the rolling circle, describe an arc cutting the arc *pg* in *p*, which will be one point of the epicycloid. Similarly, any number of points may be found.

To draw a tangent to the curve at any point as *p*, a line is drawn from *p* to the instantaneous center g', and the tangent will be perpendicular to this line.

26. The *hypocycloid* is a plane curve which may be generated by a point in the circumference of a circle rolling on the concave arc of another circle to which it is tangent internally.

PROB. 101. To construct the hypocycloid and a tangent to the curve.

The construction of this curve is in close analogy to that of the epicycloid. The construction may be easily understood from Fig. 49, which is lettered to correspond with Fig. 48.

Besides the cycloidal curves already given there are others of less importance. If two circles are tangent internally, and if the larger one rolls upon the smaller, a point in the circumference of the larger circle will generate an *internal* epicycloid or *pericycloid*. If the generating point instead of being on the circumference of the rolling circle is within or without the circumference, other curves are traced. When the circle rolls on a right line, upon another circle in external contact, on another smaller circle in internal contact, or in a larger circle in internal contact, the point within the rolling circle will generate a *prolate trochoid*, *prolate epitrochoid*, *prolate peritrochoid* or *prolate hypotrochoid*, respectively. If the generating point be beyond the circumference of the rolling circle on a radius produced, under conditions as to directrix taken in the same order as just given, it will generate a *curtate trochoid*, *curtate epitrochoid*, *curtate peritrochoid*, or *curtate hypotrochoid*. All of these curves can be readily constructed.

The invention of the cycloid is attributed to Galileo, but it is known that the trochoids were employed by mathematicians, possibly two thousand years before the time of Galileo. Old astronomers explain the motion of the planets on the assumption that they move around a circle whose center moves around another circle.

27. An *involute* of a circle is a plane curve generated by a point in a straight line which rolls on the circumference of a circle. This curve is described by any point in a cord which is kept in tension while it is unwound from a cylindrical spool.

This involute is the proper curve for the working faces of cams in stamp mills. The epicycloid, when the radius of the moving circle is infinity, becomes an involute of a circle.

PROB. 102. To construct an involute of a circle, and a tangent to the curve.

In Fig. 50, r is the center of a given circle, and o is the generating point in a right line tangent to the circle at that point. A point in the involute may be found by drawing a tangent to the circle at any point as b, and rectifying on the tangent the arc from b to o, giving the point p of the involute. Similarly, any number of points may be found.

A tangent to the curve at any point, as p, will be perpendicular to the line pb, which is tangent to the circle at b.

28. The *Conchoid of Nicomedes* * is the locus of a point moving in a straight line which rotates about a fixed point on the line called the pole, the generating point always remaining at a constant distance from a given line called the directrix.

PROB. 103. To construct the Conchoid of Nicomedes. In Fig. 51, o is the pole, AB is the directrix, and mn is the constant distance. Any point of the curve may be found by drawing a line as op through the pole, and by taking the distance $rp = mn$, giving the point p. Similarly, any number of points may be found. If the constant distance be laid off above AB, on the line op, another point a of the curve will be established. Thus the curve is seen to have two branches on opposite sides of AB.

This curve may be used in trisecting a plane angle. In Fig. 51, let nop be the given angle. A conchoid is constructed, having one side of the angle as on perpendicular to the directrix AB, and the vertex of the angle is taken as the pole, with the constant distance $mn = 2\ or$. It is assumed that the curve has been so constructed. A line rv is drawn parallel to mn, intersecting the curve at v. Joining o and v gives the angle $nov = \frac{1}{3}\ nop$. Proof: —

$$lv = mn = 2\ or;$$
$$rv = lv \cos lvr = 2\ or \cos nov;$$
$$rv : or :: \sin vor : \sin nov;$$
$$\therefore \sin vor = 2 \sin nov \cos nov$$
$$= \sin 2\ nov.$$
$$\text{Hence, } \angle\ vor = 2 \angle\ nov.$$

---

* Probably the three most famous problems of the ancients were the squaring of the circle, the duplication of the cube, and the trisection of an angle. One of the most interesting curves invented by these early mathematicians for the purpose of trisecting an angle was the conchoid.

29. The *logarithmic spiral* is a plane curve whose construction depends on this property: Any radius vector which bisects the angle between two other radii is a mean proportional between them.

PROB. 104. To construct the logarithmic spiral.

In Fig. 52, *r* is the pole, and two points, as *a* and *e*, on opposite sides of the pole are assumed to be on the curve. Another point as *c* may then be found by drawing *rc* perpendicular to *ae*, intersecting a circle on *ae* as diameter in the point *c*, $\therefore rc^2 = ar \times re$ as required. If *eg* is drawn perpendicular to *ce* until it intersects *cr* produced, the intersection *g* will be another point of the curve. Similarly, any number of points may be found. This spiral is frequently called the *equiangular* spiral, from the fact that the angle between any radius vector and the tangent to the curve at its extremity is constant.

The logarithmic spiral is used in designing speed-pulleys, and for the outlines of spiral cams and lobed wheels. The logarithmic spiral may be constructed more readily as follows: Any two lines are drawn intersecting each other as *ON* and *OM* in Fig. 53. Near the vertex any line as *ax* is drawn intersecting *ON* and *OM*. Then with *O* as a center and *Ox* as a radius, the arc *xb* is drawn. Then through the point *b*, where the arc intersects *OM*, the line *by* is drawn parallel to *ax*. And again with *O* as a center, and *Oy* as a radius, the arc *yc* is described and so on, until as many points *a*, *b*, *c*, *d*, etc., are obtained as may be desired. It may be readily proved that any one of these distances as *Of* is a mean proportional between the distances *Og* and *Oe* between which it lies. Radii of a circle running to points of equal division on the circumference are now constructed, and the distances, *Oa*, *Ob*, *Oc*, etc., are laid off on successive radii. The curve connecting the points thus obtained will be the logarithmic spiral.

30. The *spiral of Archimedes* is a plane curve which may be generated by a point moving uniformly along a right line, which rotates uniformly about one of its points. The moving line is called the *radius vector*, and the stationary point is the *pole*.

PROB. 105. To construct the spiral of Archimedes.

Take any point as *r* for a center, as in Fig. 54, and describe a circle with any radius, as *ra*. Then divide this circle into any number of equal parts as $ab = bc = cd$, etc. Assume any point on one of the radii as p_1 on *ra* as one point of the required curve. Now draw the radii *rb*, *rc*, etc., and on *rb* take $rp_2 = 2\,rp_1$, and on rc take $rp_3 = 3\ rp_1$, etc. Thus points, p_1, p_2, p_3, etc., points on the curve, may be constructed.

To draw a tangent to the spiral of Archimedes at any point of the curve, as p_3, any two radii vectors as rx and ry are drawn, making an angle with each other equal to a radian, 57° 29, intersecting the spiral in the points x and y. Then a circle is drawn with its center at r, and having a radius equal to the difference between ry and rx. A line through p_3 tangent to this circle will be normal to the curve at p_3.

31. The *sinusoid* is a plane curve which may be generated by a point moving in a plane, so that in any position its distance from a given right line is equal to the sine of an arc, which is proportional to the distance the point has passed in a direction parallel to the fixed line.

PROB. 106. To construct the sinusoid.

The curve may be constructed by a system of rectangular co-ordinates, taking the abscissas proportional to arcs of a circle, while the corresponding ordinates are sines of the arcs.

The sinusoid is the vertical projection of a helix, which construction is given in the next problem.

This curve expresses the law of vibration of perfectly elastic solids, and the law of the vibratory movement of the pendulum.

PROB. 107. To construct Schiele's anti-friction curve.

In Fig. 55, ab is the radius of the shaft and bc its axis. The axis bc is divided into equal small divisions at the points 1, 2, 3, etc. The line 1-a is drawn. Then with point 2 as a center, and a radius equal to ab, an arc is described cutting the line 1-a in d, one point of the curve. Similarly, any number of points of the required curve ae are constructed.

32. The ordinary *helix* is a curve generated by a point moving on the surface of a cylinder of revolution, so as to cut all the elements at a constant angle. The moving point has uniform motion around the axis of the cylinder combined with uniform motion parallel to it.

PROB. 108. To construct the projections of a helix and a tangent to the curve at any point, and also to develop the curve on a plane surface.

If the helix be taken in the convex surface of a cylinder standing on H, its horizontal projection is evidently a circle. In Fig. 56, let the circle $a^hp^hc^h$ be the horizontal projection of the curve, and M its axis. Let it be assumed that the generating point rises a distance a^vb^v in making one complete revolution. Divide the circle $a^hp^hc^h$ and the line a^vb^v into the same number of equal parts, say eight. Taking the generating point in the initial position at a, when the point has moved one-eighth the distance around the axis, it will be horizontally projected at p^h. But in this time it will have risen the height a^vm, or one-eighth of a^vb^v. Therefore the intersection of a line through m, parallel to GL with a line through p^h perpendicular to GL, gives the vertical projection p^v. Similarly, the projections of any number of points in the curve may be found.

If the convex surface of the cylinder containing the helix be developed on a plane surface, the helix will develop into a straight line.

The sinusoid shown in Fig. 56 is the vertical projection of the helix that crosses the elements of a cylinder of revolution at an angle of 45°.

In Fig. 56, the height a_vb_v is called the pitch. The helix is used in designing screws, screw-propellers, winding-stairs, skew-arches, etc.

The angle which any element of the curve makes with H, is the angle at the base of a right triangle having the horizontal projection of the element for its base, and the difference of the heights of the extremities of the element for its altitude. But the angle made by this element with H is the angle which the tangent to the curve at that point makes with H, and evidently any arc of the curve is to its horizontal projection as an element is to its projection on H. Hence, to draw a tangent to the curve at any point p, a tangent is drawn to the circle at p^h, which will be the horizontal projection of the required tangent. The arc pa is then developed on p^hr^h, giving r^h, which is the horizontal trace of the required tangent. The vertical projection is r^vp^v.

In Fig. 57 is shown an approximate construction of a tangent to a plane curve, which is useful when no exact method is known. Let *MN* be an irregular curve, and *t* the point of tangency. Two or three points near to *t*, and on each side of it, are taken, and through these points and *t* secants are drawn as *tn*, *to*, *tr*, *ts*, etc. Then with *t* as center, any circle as *xy* cutting these secants is drawn. Along each of the secants, as *pp'*, a distance from the circle *ap'* = *pt* is laid off, giving the point *p'*. Connecting points found in this way gives the curve *p't's'*, which cuts the circle in *t'*. *tt'* is the required tangent.

A tangent is drawn to an irregular curve from an exterior point by passing a straight edge through the point so as to touch the curve. If the curvature of the curve is slight, the exact point of contact is not apparent. In Fig. 58 is shown a method for finding the point of tangency in such a case. *Tt* is a tangent to the curve *MN*. A secant, as *ab*, near *Tt* and parallel to it, is drawn. At *a*, a perpendicular to *Tt* is drawn downwards, and at *b* another is drawn upwards. The points *c* and *d* are found by taking *lc* = *bd* = *ab*. Similarly, other points as *e*, *f*, *g*, and *h* are found, and a line is drawn connecting these points. This line will intersect the curve in *p*, the required point of tangency.

PROB. 109. To find the projections of a circle lying in a plane whose traces are given.

PROB. 110. To find in Fig. 59 where the irregular curve *ab* intersects the planes of projection and the plane *R*.

PROB. 111. To construct the projections of a helix whose axis is inclined to both planes of projection.

CHAPTER IV.

SURFACES.

Art. 17. Generation and Classification of Surfaces.

33. A surface may be generated by a line moving according to some law. This line is called the *generatrix*, and the different positions of the line are *elements* of the surface. The kind of the surface is determined by the form of the generatrix and the law of its motion.

Surfaces may be grouped under two general classes. First: Surfaces that may be generated by right lines. These are called *ruled surfaces*. Second: Surfaces that can only be generated by curves. These have no rectilinear elements, and are called *double curved surfaces*.

There are three kinds of ruled surfaces. First: *Planes*, which may be generated by a right line intersecting and moving along another right line, always remaining parallel to its first position. Second: *Single curved surfaces*, which may be generated by a right line moving so that any two of its consecutive positions shall be in the same plane. Third: *Warped surfaces*, which may be generated by a right line moving so that no two of its consecutive positions shall be in the same plane.

There are three kinds of single curved surfaces. First: *Cylindrical* surfaces, in which all the positions of the rectilinear generatrix are parallel. Second: *Conical* surfaces, in which all the positions of the rectilinear generatrix meet in a point. Third: *Developable* surfaces, in which the consecutive positions of the rectilinear generatrix intersect two and two, no three positions intersecting in a common point.

Art. 18. Single Curved Surfaces and Tangent Planes.

34. Any *cylinder* may be generated by a right line moving so as to touch a curve and have all its positions parallel. The curve is the *directrix*, the moving line is the *generatrix*, and any position of the moving line is an *element* of the surface. The intersection of the cylinder by a horizontal plane is usually taken as the *base*. Cylinders are commonly named according to the forms of their bases. If the base is a circle, the cylinder is called a circular cylinder; if the base is an ellipse, the cylinder is said to be an elliptical cylinder, etc. If the base is a central curve, the line through the center of the base parallel to the rectilinear elements is called the *axis*. When the elements of a cylinder are perpendicular to the base, it is called a *right* cylinder, but if the elements are oblique to the base, it is an *oblique* cylinder.

35. The lines projecting a curve on one of the planes of the projection are elements of a right cylinder, and the base of this cylinder in the plane is a projection of the curve. The cylinder projecting the curve on H will be called the H-projecting cylinder, and the cylinder projecting the curve on V, the V-projecting cylinder. These two projections of a curve completely determine it.

36. A plane is tangent to a surface when it touches it in at least one point, if any plane passing through this point intersects the given surface and its tangent plane in lines that are tangent to each other. If it is required to find the plane tangent to a given surface at a given point of contact, any two plane curves on the surface which pass through the given point may be found, and the required tangent plane will be determined by the lines tangent to these curves at the given point.

If a plane contains two consecutive elements of a single curved surface, it will be tangent to the surface and tangent at every point along an element. Because any secant plane passed through any point of one of the consecutive elements will intersect the other in a consecutive point, and the line joining these consecutive points will lie in the tangent plane, and will be tangent to the curve cut from the surface.

If a curve and a tangent to it be projected on a plane, the projection of the right line will be tangent to the projection of the curve, because the projecting plane of the line will be tangent to the projecting cylinder of the curve, and the intersections of the plane of projection with the projecting plane and projecting cylinder will be tangent to each other.

PROB. 112. To construct the projections of a cylinder, and to assume a point on the surface.

In Fig. 60, $a^h b^h c^h$, the base in H, is first drawn. The center of the base, o, is the horizontal trace of the axis. The axis M is next assumed. S^h and T^h are drawn parallel to M^h and tangent to $a^h b^h c^h$. The base is projected on V in $d^v b^v$. Through d^v and b^v lines V^v and W^v are drawn parallel to M^v. The lines S, T, V, and W are called lines of *apparent contour.*

To find a point on the surface: Assume one projection of such a point as x^h. G^h, drawn through x^h parallel to M^h will be the horizontal projection of an element containing x. The intersection, k^h, of G^h with $a^h b^h c^h$ will be the foot of the element in H, which is vertically projected in k^v. G^v drawn through k^v parallel to M^v is the vertical projection of this element. x^v, the intersection of a perpendicular to GL through x^h with G^v, is the vertical projection of the point x. J^v is the vertical projection of another element which is horizontally projected in G^h, hence another point as z may be found which is horizontally projected in x^h.

PROB. 113. To pass a plane tangent to a cylinder at a point on the surface.

Analysis. If a plane be tangent to a cylinder at a point on the surface, it will be tangent to the cylinder all along the element. Any plane cutting this element will intersect the cylinder and the tangent plane in lines that will be tangent to each other. Then, if the base of the cylinder be taken in H, the line cut by H from the tangent plane must be tangent to the base which is cut from the cylinder; i.e., the horizontal trace of the tangent plane is tangent to the base of the cylinder. One point of the vertical trace of the tangent plane is found by drawing through any point of the element of contact a horizontal of the plane, and getting its vertical trace.

In Fig. 61, *a* is the given point on the surface, and *M* is the element of contact. *HX*, tangent to the horizontal projection of the base of the cylinder at k^h, the horizontal trace of *M*, is the horizontal trace of the tangent plane. A horizontal of the tangent plane through *a* intersects *V* in g^v, through which *VX* is drawn.

PROB. 114. To construct the projections of a right circular cylinder having its axis parallel to *GL*, to find a point on the surface, and to pass a plane tangent to the surface at this point.

PROB. 115. A cylinder whose right section is a circle of $\frac{3}{4}''$ radius has its axis inclined at 30° to *H* and 45° to *V*. To find the intersections of the cylinder with *H*, *V* and *P*.

PROB. 116. To pass a plane through a point without a cylinder tangent to the surface.

Analysis. Through the given point a line is drawn parallel to the elements of the cylinder. This line must lie in the tangent plane, and therefore its horizontal trace will be one point of the horizontal trace of the required plane. A line drawn through this point tangent to the base of the cylinder in *H* will be the required horizontal trace. The vertical trace may be found as in Prob. 113.

PROB. 117. To pass a plane tangent to a cylinder and parallel to a given right line.

Analysis. The required tangent plane must be parallel to the given line, and also parallel to the elements of the cylinder. Hence, if a plane be passed through the given line parallel to an element of the cylinder, it will be parallel to the required plane, and its traces will be parallel to the required traces. Therefore, a line tangent to the base of the cylinder, and parallel to the horizontal trace of this auxiliary plane, will be the required horizontal trace. The vertical trace may be obtained as before.

37. A *cone* may be generated by a right line moving so that it always passes through a given point and touches a given curve. The given point is the *vertex*, and the given curve is the *directrix*. The generatrix being indefinite in length, will generate two portions of the surface on opposite sides of the vertex, called the *upper* and *lower nappes*.

The intersection of the surface with H is usually taken as the *base*. Cones are named with reference to the forms of their bases. If the base is a circle it is called a circular cone; if an ellipse, it is called an elliptical cone, etc. If all the rectilinear elements make equal angles with a right line through the vertex, the cone is a *right cone* or a *cone of revolution*, and the right line is its *axis*. Evidently any plane through the vertex of the cone that intersects the surface will cut two elements from the cone.

PROB. 118. To draw the projections of a cone and to assume a point of the surface.

In Fig. 62, the base $a^h b^h d^h$ in H, and the projections of the vertex v, are assumed. Tangents to the base from v^h complete the horizontal projection of the surface. The base is projected vertically in $a^v b^v$, and lines drawn from v^v to a^v and b^v complete the vertical projection $a^v v^v b^v$ of the cone.

The elements S, T, V, and W are the elements of apparent contour.

A point on the surface is found by first assuming one of its projections as x^h. The line E^h drawn through v^h and x^h, will be the horizontal projection of two elements, either of which may contain the point x. The vertical projections of the elements are E^v and F^v. Therefore, the vertical projection of the required point may be x^v or z^v.

PROB. 119. To pass a plane tangent to a cone at a point on its surface.

Let the cone be given as in Fig. 63, with vertex o, and base bfc, and let p be the point of tangency. HX is drawn tangent to the base of the cone at f^h, the horizontal trace of the element of contact. One point, g^v, of the vertical trace is found as in Prob. 113.

PROB. 120. To pass a plane through a given point without a cone tangent to the surface.

Analysis. The tangent plane must contain an element of the cone, and hence must pass through the vertex. It also passes through the given point, and hence must contain the line connecting the given point with the vertex. The horizontal trace of this line will be a point in the horizontal trace of the required tangent plane, which is drawn tangent to the base of the cone. The vertical trace may be found as before.

PROB. 121. To pass a plane tangent to a cone and parallel to a given right line.

Analysis. If a line be drawn through the vertex of the cone parallel to the given line it will lie in the required plane, and hence its horizontal trace will be a point in the trace of the required tangent plane. Through this point a line tangent to the base will be the required horizontal trace. The vertical trace may be found as before.

PROB. 122. A right circular cone, the radius of the base being 1″ and altitude 2″, stands on *H*. If light comes from a point ½″ above the vertex and 1″ from the axis, to find the line of shade on the cone and the shadow on *H*.

PROB. 123. To construct the traces of a plane that shall make a given angle with one of the planes of projection and that shall contain a given line.

In Fig. 64, let M be the given line, and ϕ the given angle which the plane is to make with H. Assume any point as a of the given line, and draw through a the line A parallel to V and making the required angle with H. Revolve A about a^h—a^vc^v as a vertical axis. The line A will describe a right circular cone whose base is $k^hl^hm^h$. Any plane tangent to this cone will make the required angle with H. The horizontal trace of M is t^h, and a line HX through t^h tangent to $k^hl^hm^h$ will be the required horizontal trace. The vertical trace is VX.

38. *Developable surfaces,* or the third kind of single curved surfaces, may be generated by moving a right line along a curve of double curvature so that in every position it is tangent to the curve. If w, x, y and z be consecutive points along a curve of double curvature, the tangent which contains the points w and x will intersect the consecutive tangent which contains the points x and y in x. The next consecutive tangent which passes through y and z will intersect the one just before it in y, but will not intersect the one through w and x. Thus each element of the surface intersects the preceding consecutive one, but no other preceding one lies in the same plane. Developable surfaces are so called because they will admit of development on a plane.

The principal surface of this kind is the *developable helicoid.* It may be generated by a right line moving so that it is always tangent to a helix.

PROB. 124. To construct elements of a developable helicoid and to assume a point on the surface.

In Fig. 65, let *abcd* be the helical directrix. Since the rectilinear elements of the surface are successive tangents to the helix, as many elements as required may be constructed by Prob. 108.

The lower base, or the intersection of the surface with H, is evidently the involute of a circle. If a horizontal plane be passed at a height above H equal to the pitch of the helix, the intersection of this plane with the surface may be called the upper base.

To assume a point on the surface, a point may be taken on any element. Or, the horizontal projection of any point may be assumed as e^h, and a line S^h through e^h tangent to $a^hb^hc^hd^h$ will be the horizontal projection of the element containing e. The vertical projection of the element, S^v, may now be found, giving the required vertical projection at e^v.

PROB. 125. To construct the traces of a plane tangent to a developable helicoid at any point on the surface.

In Fig. 65, let e be the given point of tangency. The tangent plane is tangent to the surface all along the element S through e. Therefore, a tangent HX to the base at the horizontal trace of the line S will be the required horizontal trace.

The vertical trace VX may be obtained in the same manner as with the curved surfaces already given.

PROB. 126. To pass a plane through a point without a developable helicoid and tangent to the surface.

Analysis. With the given point as a vertex a cone of revolution is constructed whose elements make the same angle with H as the elements of the given surface. A plane tangent to this cone and to the helicoid will be the required plane. A line tangent to the bases of both surfaces must be the required horizontal trace. The horizontal trace determines parallel elements of contact in the two surfaces by which the required vertical trace can be readily found.

PROB. 127. To pass a plane tangent to a developable helicoid and parallel to a given right line.

Analysis. A plane is passed through the given line making the same angle with H that the elements of the given surface make. The horizontal trace of the required tangent plane will be parallel to the horizontal trace of the plane just found. The required horizontal trace will also be tangent to the base of the developable helicoid. The vertical trace may now be found as before.

Art. 19. Surfaces of Revolution.

39. A surface, which may be generated by a right line or a plane curve revolving about a right line in the same plane as an axis, is a *surface of revolution.*

The right circular cylinder and the right circular cone are the only single curved surfaces that are surfaces of revolution.

Evidently, the intersection of a surface of revolution by a plane perpendicular to its axis is a circle.

If a surface of revolution be intersected by a plane through the axis, the line of intersection is called a *meridian line.* The meridian line parallel to V is sometimes called the *principal meridian.*

A *normal line* to a surface at any point is a right line through that point perpendicular to the plane which is tangent to the surface at that point.

A *normal plane* to a surface at any point is a plane perpendicular to the tangent plane at that point.

Some of the principal double curved surfaces of revolution are the sphere, ellipsoids, paraboloid, hyperboloids and the annular torus.

40. PROB. 128. To draw the projections of a sphere, to assume a point on the surface, and to construct a plane tangent to the surface at any point of the surface.

Each projection of the sphere will evidently be equal to a great circle of the sphere, and its center will be one projection of the center of the sphere. The projections of a sphere may then be taken as in Fig. 66, $a^h b^h c^h$ being the horizontal, and $a^v d^v c^v$ the vertical projection.

To assume a point on the surface, one projection as e^h is first assumed. *HD* passing through e^h and o^h is the horizontal trace of the meridian plane through e. This plane is revolved about the vertical axis of the surface until it becomes parallel to *V*. After revolution, the meridian curve cut by *D* coincides with the principal meridian $a^h c^h$ — $a^v d^v c^v$, and the revolved position of e is e_1. In the counter-revolution e_1 describes a horizontal arc which is vertically projected in $e_1{}^v e^v$. The vertical projection e^v of the required point is where a line through e^h perpendicular to *GL* intersects $e_1{}^v e^v$. f^v, similarly found, is the vertical projection of another point having e^h for its horizontal projection.

A plane *X* tangent to the surface at a point e will pass through the point e and be perpendicular to the radius of the sphere terminating in e.

PROB. 129. Given a sphere whose diameter is 3″ and whose center is in *H*, 1″ from *V*. To pass a plane tangent to the sphere and inclined 30° to *H* and 45° to *V*, and to find the point of tangency.

41. The *ellipsoid* is generated by revolving an ellipse about either axis. If the ellipse is revolved about its transverse axis, the surface is a *prolate* ellipsoid; if revolved about its conjugate axis, the surface generated is an *oblate* ellipsoid. The ellipsoids are sometimes called *spheroids*.

PROB. 130. To construct the projections of an ellipsoid, to assume a point on the surface, and to pass a plane tangent to the surface at a point on the surface.

In Fig. 67, M is the transverse axis which is taken as the axis of revolution perpendicular to H. The horizontal projection of the surface is the horizontal projection of the greatest *parallel*, *abc*, or circular section perpendicular to the axis. The vertical projection of the surface is the vertical projection of the principal meridian.

A point e of the surface is assumed as in PROB. 128.

To construct the tangent plane: The plane tangent to the surface at any point as e contains the tangent to the meridian curve at e and is also perpendicular to the normal to the surface at this point. G_1 is drawn tangent to the principal meridian at e_1, and H_1 is the normal at e_1. After the counter-revolution, the tangent takes the position G, and the normal comes to H. The normal intersects the axis in the point k. The tangent plane contains the tangent G, and is perpendicular to the normal H. Therefore, the required horizontal trace HX passes through t^h and is perpendicular to G^h, and the required vertical trace is perpendicular to H^v.

42. The *paraboloid* may be generated by revolving the parabola about its axis.

PROB. 131. To draw the projections of a paraboloid, to assume a point on the surface, and to construct a plane tangent to the surface at a point on the surface.

The best position for the axis is a position perpendicular to H or V.

A point is assumed on the surface, and a plane tangent to the surface at this point is constructed as in the preceding problem.

43. The *hyperboloid of revolution of two nappes* may be generated by revolving a hyperbola about its transverse axis.

PROB. 132. To draw the projections of a hyperboloid of revolution of two nappes, to assume a point on the surface, and to construct a plane tangent to the hyperboloid at a point on the surface.

A point is assumed on the surface, and a plane tangent to the surface at this point is constructed as in Prob. 130.

44. An *annular torus* may be generated by a circle revolving about an axis without the circle, and in the same plane with it.

PROB. 133. To draw the projections of an annular torus, to assume a point on the surface, and to construct a plane tangent to the torus at a point on the surface.

A point is assumed on the surface, and a tangent plane is constructed as in Prob. 130.

PROB. 134. To pass the surface of a sphere through any four points not in the same plane.

Analysis. If the four points be connected by three lines, and a plane be passed perpendicular to each of these lines at its middle point, three planes will be found which will pass through the center of the sphere. The right line connecting the center with one of the given points will be the radius whose true length is then obtained.

PROB. 135. To pass a plane through a given right line and tangent to a sphere.

Analysis. A secant plane is passed through the center of the sphere perpendicular to the given line, and its intersections with the line and sphere are found. From the intersection of the secant plane and the given line, two lines are drawn tangent to the great circle in which the secant plane cuts the sphere. A plane containing the given line and either one of these tangents to the spherical section will be a required tangent plane.

In Fig. 68, M is the given line, and c is the center of the given sphere.

1st. To pass a plane through c perpendicular to M. This plane is determined by the two lines G and I through c, constructed parallel respectively to the horizontal and vertical traces of the plane. The intersection h of the plane (G, I) with the line M is found by Prob. 45.

2d. To construct a tangent line from h to the circle cut from the sphere by the plane (G, I). If the plane (G, I) be revolved about G until it becomes parallel to H, the circle cut from the sphere by it will be horizontally projected in $k_1n^ho^h$, and the point h will revolve to h_1. The line J_1 from h_1, tangent to $k_1n^ho^h$ at k_1, will be the revolved position of a tangent line. After the counter-revolution of the tangent the point h_1 is at h, and m is in the axis of revolution; therefore h^hm^h is the horizontal projection of the tangent, and k^h is the horizontal projection of the point of tangency. The point m is vertically projected in m^v, and h^vm^v is the vertical projection of the tangent line.

3d. The plane of the lines M and J, or the plane X, is the required plane. The tangent plane is perpendicular to the radius that terminates at the point of tangency. Therefore HX must be perpendicular to L^h, and VX perpendicular to L^v.

Art. 20. Intersections and Developments.

45. The intersection of a right line or a curve of single curvature with a surface may be found by passing any plane through the line, intersecting the surface. The intersection of the given line with the line cut from the surface by the plane will be the required point. The plane should be selected so as to cut the surface in the simplest line possible.

The intersection of a plane with a surface may be found by cutting the given plane and surface by a system of auxiliary planes. Each auxiliary plane will cut from the given plane and surface lines whose intersections will be points of the required line.

The intersection of any two curved surfaces may be found by intersecting them by a system of auxiliary surfaces. Each auxiliary surface will cut from the given surfaces lines whose intersections will be points of the required line. The system of auxiliary surfaces should be assumed so that the simplest lines possible will be cut from the given surfaces.

46. A right line tangent to the curve of intersection of two surfaces at any point of the curve may be found by passing a plane tangent to each surface at this point. The intersection of these two planes will be the required tangent.

47. If a single curved surface be rolled upon a plane tangent to it, until all its rectilinear elements come successively into contact with the plane, the equivalent plane surface covered by the given surface will be the *development of the surface*.

PROB. 136. To find the intersection of a right circular cylinder by an oblique plane, to draw a tangent to this curve of intersection, to show the curve in its true size, and to develop the cylinder and the curve.

Analysis. Let the cylinder be given as in Fig. 69, R being the cutting plane. The cylinder and plane R are cut by a system of planes parallel to the axis of the cylinder and the horizontal trace of the cutting plane. Each of these auxiliary planes will cut from the cylinder two elements, and from the plane R a line parallel to H. The intersections of the elements cut from the cylinder and the line cut from R will be points of the required curve.

1st. The auxiliary plane L cuts the cylinder in elements projected vertically in I^v and J^v. This plane L cuts the plane R in the line vertically projected in K^v. The intersections of line K with lines I or J, or m and n, are two points of the required intersection. Similarly, any number of points may be found.

It may be shown that a plane through the axis of the cylinder perpendicular to the plane R, intersects R in a line which contains the transverse axis of the elliptical section.

2d. To draw a tangent to the curve at any point n. A plane is passed tangent to the cylinder at this point. The horizontal trace of this tangent plane is HT. The intersection of this tangent plane with the plane R, is T, the tangent line required.

3d. To find the curve of intersection in its true dimensions, the plane R is revolved about HR into H, and the revolved positions of points on the curve are found. T_1 is the revolved position of the tangent T.

4th. It is assumed that the cylinder is cut along the element J, opposite to the element through g. In Fig. 69*a*, the element through g is taken at kg_1. The cylinder develops into a rectangle *ablo*, whose altitude *ao* is equal to the altitude of the cylinder, and whose base *lo* is equal to the rectified base of the cylinder. The developed position of any point *n* of the curve of intersection is found by laying off from *k* to n_1 the rectified arc $g^h n^h$, and erecting a perpendicular to *lo* at n_1. The developed position n' is at a distance from *lo*, equal to the distance from n^v to *GL*.

PROB. 137. To find the intersection of a plane with an oblique cylinder, to draw a tangent to the curve of intersection at any point, and to show the curve in its true dimensions.

Analysis. The plane and cylinder are intersected by a system of planes parallel to the elements of the cylinder and perpendicular to *H.* Each of these planes will intersect the cylinder in two elements, and the given plane in a line, whose intersections are points of the required curve.

A tangent to the curve at any point is the intersection of a plane tangent to the cylinder at that point and the given plane.

The curve in its true dimensions may be found as in the preceding problem.

PROB. 138. To find the intersection of a plane with a right circular cone, to draw a tangent to the curve of intersection at any point, and to develop the cone and the curve.

Let the cone be given as in Fig. 70, and let *R* be the given plane.

1st. Planes are passed through the vertex of the cone perpendicular to *V.* Each of these planes will cut the cone in two elements, and the given plane in a line whose intersections are two points of the required curve. Let one of the planes be *D.* It cuts from the cone elements horizontally projected in I^h and J^h, and it cuts the plane *R* in the line horizontally projected in K^h. The intersections *e* and *f* of the line *K* with the lines *I* and *J* are two points of the required curve.

2d. To draw a tangent to the curve at any point, as *f.* A plane, whose horizontal trace is *HU,* is passed tangent to the cone at the point *f.* The intersection *T* of this plane with plane *R* is the required tangent.

3d. To develop the surface. It is assumed that the surface is cut along any element, as ca, and rolled on the plane tangent at this element. With any point, as c' in Fig. 70*a*, as a center, and with $c'a' = c^va^v$ as a radius, an indefinite arc $a'a''$ is drawn. The circle $a^hb^hd^h$ is developed from a' to a''; then the circular section $c'a'a''$ is the development of the cone.

To find the development of any point as e, in the curve of intersection, the element ce is revolved about the axis of the cone until it is parallel to V. Then it will coincide with the element ca, and the true length of ce is shown at c^ve_1. If the arc a^hg^h be developed from a' to g' on $a'a''$, then $c'g'$ will be the development of the element cg. And the distance c^ve_1, measured from c' along $c'g'$, will give e', the developed position of e.

Prob. 139. To pass a plane so as to cut a conic section from a right circular cone, and to show the curve in its true dimensions.

A plane parallel to the base will intersect the cone in a *circle*. If the cutting plane makes a smaller angle with the base than the elements do, the curve is an *ellipse*. If the secant plane is parallel to an element, it cuts the cone in a *parabola*; and if the plane makes with the base a greater angle than the elements, the curve is a *hyperbola*.

Prob. 140. To find the intersection of a plane with any oblique cone, and to draw a tangent to the curve of intersection at any point of the curve.

Analysis. Auxiliary planes intersecting the cone are passed through the vertex of the cone perpendicular to H. Each of these planes cuts two elements from the cone, and a line from the given plane whose intersections are points of the curve.

A tangent to the curve of intersection at any point may be constructed as in Prob. 138.

Prob. 141. To find the intersection of a plane with any surface of revolution, and to draw a tangent to the curve of intersection.

Analysis. Auxiliary planes are passed perpendicular to the axis. Each of these planes cuts a circle from the given surface, and a right line from the given plane, whose intersections are points of the required curve. If the axis be taken perpendicular to one of the planes of projection, the projections of the circular intersections are readily found.

A tangent to the curve of intersection is found as before by passing a plane tangent to the surface at the given point, and finding the intersection of this tangent plane with the given plane.

Let the surface be the annular torus given as in Fig. 71, and let R be the secant plane. The auxiliary horizontal plane whose vertical trace is VL, intersects the surface in two circles, horizontally projected in G^h and J^h, and intersects the plane R in a line horizontally projected in K^h. The intersections e, f, g, and h of K, with G and J, are points of the required curve. Similarly, any number of points may be found.

To draw a tangent to the curve of intersection at any point g. By Prob. 130, the tangent plane to the surface at g is X. The tangent plane intersects the plane R in the required tangent T.

PROB. 142. To find the intersection of a triangular pyramid with a sphere.

PROB. 143. To find the intersection of a cone and a cylinder, and to draw a tangent to the curve of intersection at any point.

Analysis. Auxiliary planes cutting both surfaces are passed through the vertex of the cone, and parallel to the rectilinear elements of the cylinder. Each of these planes will intersect each of the surfaces in two elements whose intersections are points of the required curve.

Let the surfaces be given as in Fig. 72. A line G, through the vertex of the cone parallel to the elements of the cylinder, will be a line of each auxiliary plane. The horizontal trace n^h of this line will be a point of the horizontal trace of each secant plane. Through n^h, any line, as HL, is drawn intersecting both bases. HL is taken as the horizontal trace of a plane that intersects the cylinder in the elements I and J, and the cone in the elements K and D. These elements intersect in e, f, g and *h*, which are four points of the required curves. Similarly, any number of points may be found.

The tangent to a curve of intersection at any point, as *f*, may be found by passing a plane tangent to each surface at *f*, and getting the intersection of these two tangent planes. *HU* and *HK* are the horizontal traces of these planes, and the required tangent line *T* is the intersection of these planes.

The plane *E*, tangent to the cylinder along the element *A*, cuts from the cone the two elements *B* and *C*. The elements of the cone between *B* and *C* in front do not intersect the cylinder; hence the curves of intersection are tangent to the elements *B* and *C* at the points *l* and *f*. Similarly, the plane *F*, tangent to the cylinder on the other side, cuts two elements *M* and *H* from the cone that are tangent to the curves.

When two auxiliary planes, as *E* and *F*, tangent to the cylinder, both intersect the cone, it is evident that the cylinder penetrates the cone, giving two distinct curves of intersection. If one of these tangent planes intersects the cone, and the other does not, there will be a single curve of intersection. If neither of these tangent planes intersects the cone, and the cone lies between them, the cone penetrates the cylinder, giving again two distinct curves of intersection.

PROB. 144. Let the base of the cylinder be in *H* and the base of the cone in *V*. To find the intersection and tangent as in the preceding problem.

PROB. 145. To find the intersection of two cylinders, and to construct a tangent to the curve of intersection.

Analysis. Auxiliary planes may be passed parallel to the elements of both cylinders. Each auxiliary plane that intersects the cylinders will cut two elements from each, whose intersections will be four points of the required intersection.

Let the cylinders be given as in Fig. 73. Through *a*, one point of the element *G*, a line *A* is drawn parallel to the elements of the other cylinder. *HS* connecting n^h and m^h, the traces of *G* and *A* respectively, will be the horizontal trace of a plane parallel to the elements of both cylinders. Any line as *HU* parallel to *HS*, and intersecting the bases of both cylinders, may be taken as the horizontal trace of an auxiliary plane. The plane *U* cuts the cylinders in the elements *I*, *J*, *K* and *H*, whose intersections *e*, *f*, *g*, and *h* are four points on the required curves. Similarly, any number of points may be found.

The tangent *T* to the curve at *f* may be obtained as in the preceding problem.

PROB. 146. To find the intersection of two cones, and to draw a tangent to the curve of intersection at any point.

Analysis. Auxiliary planes may be passed through the vertices of both cones. The horizontal trace of the line connecting the two vertices will be a point common to the horizontal traces of all the auxiliary planes. Any line through this point intersecting the bases of both cones may be taken as the horizontal trace of a plane cutting two elements from each cone, whose intersections are points of the required curve.

A tangent to the curve at any point may be constructed as in the preceding problem.

PROB. 147. To find the intersection of two surfaces of revolution whose axes are in the same plane, and to draw a tangent to the curve of intersection at any point.

Analysis. If the axes of the two surfaces are parallel, an auxiliary plane perpendicular to the axes will cut circles from the surfaces whose intersections will be points of the required curve. But if the axes intersect, a system of auxiliary spheres having their centers in the point of intersection of the axes will cut both surfaces in circles perpendicular to the axes. The points of intersection of the two circles cut by such a sphere will be points of the required curve of intersection.

Let the surfaces be the ellipsoid and paraboloid whose projections are taken as in Fig. 74. The axis of the ellipsoid is perpendicular to *H*, and the axis of the paraboloid is parallel to *V*, and the axes intersect in *a*. With a^v as a center, and a^vb^v as a radius, the arc $b^vc^vd^v$ is described. The arc $b^vc^vd^v$ may be taken as the vertical projection of an auxiliary sphere. This sphere cuts from the ellipsoid the circle $b^he^hc^h - b^vc^v$, and from the paraboloïd the circle vertically projected in d^vk^v. These circles intersect in two points, e and f^h-e^v, which are points of the required curve. Similarly, any number of points may be found.

A tangent may be drawn to the curve of intersection at any point e, as in the last three problems, but another method will be given. If a normal line to each surface be drawn at the assumed point e, the plane of these normals will be perpendicular to the two planes, each tangent to one of the surfaces at e, and hence perpendicular to their intersection, which is the required tangent line.

A normal to the ellipsoid at e is constructed by revolving the meridian plane containing e about the axis of the surface until it becomes parallel to V. The meridian plane will thus be vertically projected in $b^vl^vc^v$, and e in b^v. A perpendicular G' to the tangent to $b^vl^vc^v$ at b^v is the revolved position of the normal. After the counter-revolution, the projections of this normal are $a^he^h-j^ve^v$. Similarly, the normal K to the paraboloid at the point e may be constructed. The line j^vm^v is the vertical projection of the intersection of the plane of these normals with the plane of the axes, and is hence parallel to the vertical trace of the plane of the normals. Therefore, e^vt^v, perpendicular to j^vm^v, is the vertical projection of the required tangent. The line e^hn^h is the horizontal projection of the intersection of the plane of the normals with the horizontal plane whose vertical trace is VL, and is hence parallel to the horizontal trace of the normal plane. Therefore, e^ht^h, perpendicular to e^hn^h, is the horizontal projection of the required tangent.

PROB. 148. Given two spheres, diameters 2″ and 3″, with centers 2″ apart on a line making angles of 30° and 45° with H and V. To find the traces of the plane and the radius of the circle in which the spheres intersect.

PROB. 149. To find the intersection of a cylinder and sphere.

Analysis. When the surfaces are given, as in Fig. 75, they may be intersected by auxiliary planes parallel to the elements of the cylinder and perpendicular to *H*. Each plane will cut a circle from the sphere and two elements from the cylinder, whose intersections will be points of the required curve. If each secant plane be revolved about its horizontal trace into *H*, the circle cut from the sphere will be shown in its true dimensions.

A tangent to the curve of intersection may be found as before.

PROB. 150. To find the intersection of a cone and hemisphere, and to draw a tangent to the curve of intersection at any point.

Analysis. Auxiliary planes may be passed through the vertex of the cone perpendicular to *H*. Each of these planes will cut from the cone two elements, and an arc of a circle from the hemisphere, whose intersections will be points of the required curve.

A tangent to the curve may be found as before.

PROB. 151. In Fig. 76 are shown the projections of a hexagonal washer. *M* is the axis of a cylindrical hole of $\frac{1}{4}''$ radius, which is bored through the washer. To find the intersections.

PROB. 152. A "*V*" threaded screw is generated by revolving an equilateral triangle about an axis in the same plane, one side of the triangle being parallel to the axis. The side of the triangle is $\frac{1}{2}''$, and the screw has $2''$ pitch and $3''$ outside diameter. To find the intersection of a plane parallel to the axis, and $1''$ from it.

Art. 21. Warped Surfaces.

48. In warped surfaces the movement of the generatrix is controlled by three conditions.

The *directrices* are lines or surfaces which the generatrix or moving line must touch. The *director* is a surface to which the generatrix must remain parallel.

In the common warped surfaces the directrices are lines, and the director is a plane.

Warped surfaces may be classified as follows: —

I. Warped surfaces having a plane director and two directrices.

II. Warped surfaces having three directrices.

III. Warped surfaces having a cone director and two directrices.

49. The simplest warped surface is one of the first class, the *hyperbolic paraboloid.* It may be generated by a right line moving so as to touch two rectilinear directrices not in the same plane, and always remaining parallel to a given plane director. This surface is called the hyperbolic paraboloid, because intersecting planes cut hyperbolas and parabolas from it. As the directrices approach parallelism, the surface approaches a plane as a limiting surface.

This surface is frequently employed. It is often used in masonry construction. The cow-catcher of a locomotive is usually in the form of this surface.

PROB. 153. Given the plane director and two rectilinear directrices of a hyperbolic paraboloid, to construct elements of the surface, and to assume any point on the surface.

Analysis. An element of the surface may be constructed by passing a plane through any assumed point of one directrix parallel to the plane director. The line connecting the assumed point with the point in which this plane intersects the other directrix will be an element of the surface.

A point of any warped surface may be assumed by taking a point on an element; or, the horizontal projection of a point may be assumed and a perpendicular to H erected at this point. Then a plane is passed through this perpendicular, cutting the surface in a line. The intersection of this line with the perpendicular is the required vertical projection.

In Fig. 77, let lines M and N be the directrices, and R the plane director. Construct any two lines in the plane director as I_1 and J_1. Then through any point a of N, draw lines I and J respectively parallel to I_1 and J_1. The lines I and J determine a plane parallel to R, which intersects the H-projecting plane of M in a line kl. The line kl intersects M in the point e, which is the point of intersection of the plane (I,J) with M. The line S, connecting a and e, is the required element. Similarly, any number of elements may be constructed.

PROB. 154. **To construct elements of the hyperbolic paraboloid by proportional division of the directrices, and to draw an element parallel to a given line.**

Analysis. A system of parallel planes will divide a right line into parts which are proportional to the corresponding divisions made by these planes with another right line. Hence, if the corresponding points of proportional division on the two given lines be connected by right lines, each of these lines will intersect both directrices, and be parallel to a plane which may be taken as the plane director.

To construct an element parallel to a given line, this line being parallel to the plane director. Through one of the directrices a plane is passed parallel to the given line, and the intersection of this plane with the other directrix is found. A line through this point of intersection, parallel to the given line, will be the required element.

In Fig. 78, let M and N be the given directrices. The line M is divided into equal parts, by beginning at any point as b, and laying off successively distances equal to bc. Likewise, the line N is divided, by beginning at some point as a, and laying off successively equal distances of any length as ad. Then lines ab, cd, etc. will be elements of a hyperbolic paraboloid.

The hyperbolic paraboloid is one of two *doubly ruled* surfaces. A doubly ruled surface is one in which there may be two different sets of rectilinear elements. Either directrix of one set of elements may become the generatrix of a second set. Thus each element of one generation intersects no element of its own set, but meets all the elements of the other set. Elements of the second generation may be constructed by taking any two elements of the first generation as directrices, and a plane director parallel to the directrices of the first generation.

If any two rectilinear elements of the same generation be taken as directrices with a plane director parallel to the first directrices, and a surface be generated, it will be identical with the first surface. In order to prove this, it is sufficient to demonstrate that any point of an element of the second generation is also a point of the first.

In Fig. 79, let M and N be directrices and E and F elements of the first generation, and let the plane director be H. With E and F as the new directrices, and a plane director parallel to M and N, an element S of the second generation is constructed. Through j any point of S, a horizontal plane is passed whose vertical trace is VL. The plane L will cut the directrices M and N in k and l, giving the line kl, an element of the first generation. Next, lines G and I are drawn through a and k parallel to S intersecting H in m and n. Likewise, lines D and C are drawn through b and l parallel to S. Line mt is drawn intersecting S in h. m, n and o are in the same right line as are also r, s and t. The plane (M, G) will be parallel to the plane (N, D), because both planes are parallel to the plane director of the second generation, hence their horizontal traces $m^h o^h$ and $r^h t^h$ will be parallel. The line $n^h s^h$ is then drawn. As G and I are parallel,

$$ok : ka :: o^h n^h : n^h m^h,$$

also $$rl : lb :: r^h s^h : s^h t^h;$$

but $$ok : ka :: rl : lb;$$

therefore $$o^h n^h : n^h m^h :: r^h s^h : s^h t^h,$$

and consequently $n^h s^h$ must pass through h^h. The plane containing the three parallel lines I, S and C contains also the element kl which therefore must intersect the element S at j. Thus it is proved that through any point j of the hyperbolic paraboloid, two rectilinear elements, one of each generation, may be passed.

PROB. 155. To pass a plane tangent to a hyperbolic paraboloid at a given point on the surface.

Analysis. Through the given point pass an element of each generation. A plane tangent to the surface at the given point will contain the line tangent to the curve which any plane through the point cuts from the surface. If a plane be passed through the point cutting a rectilinear element from the surface, the line of intersection is this element, and the line tangent to the line of intersection must therefore coincide with this element. Hence, the tangent plane is determined by the two elements passing through the point.

In Fig. 80, let *M* and *N* be the directrices and *H* and *O* any two elements, and assume any point of the surface as *a*. Through *a* draw *ah* and *aj* parallel respectively to lines *H* and *O*. These lines determine a plane through *a* parallel to the plane director. This plane intersects *N* in the point *e*; therefore, *ae* is an element of the first generation through *a*. Now *O* and *H* are taken as directrices, and *M* and *N* as elements for the second generation, and through *a* lines *I* and *J* are drawn parallel respectively to *N* and *M*. These lines determine a plane through *a* parallel to the plane director of the second generation. This plane intersects *H* in the point *f*; hence *af* is an element of the second generation through *a*. *X*, the plane of the lines *ae* and *af*, is the required tangent plane.

50. The *hyperboloid of one sheet* is a warped surface which may be generated by a right line revolving about an axis not in the same plane with it. This is a doubly ruled surface, and is the only warped surface of revolution.

PROB. 156. To construct elements of the hyperboloid of revolution of one nappe by revolving a right line about another not in the same plane, and to construct elements of both generations.

In Fig. 81, let *M* be the axis, and assume the line *N* parallel to *V* as one position of the generatrix. As the generatrix revolves about the axis, each point of it describes a horizontal circle. The point *a* of the generatrix, which is the nearest point to the axis, describes the circle *man*, which is called the *circle of the gorge*. $M^h a^h$ is the radius of the gorge circle, and shows the distance from the axis to the generatrix. As the generatrix in every position is at this constant distance from the axis, the horizontal projection of the generatrix in any position must be tangent to the circle $m^h a^h n^h$. The horizontal trace *k* of the generatrix *N* describes a circle $k^h l^h c^h$ on *H* which is the intersection of the required surface with *H*.

An element may be assumed by drawing a tangent E^h to the circle $m^h a^h n^h$ at any point as h^h. E^h may be taken as the horizontal projection of an element whose horizontal trace j^h is in the circle $i^h k^h j^h$. The vertical projection of h is at h^v in the vertical projection of the gorge circle, and j^v is in GL. Hence $h^v j^v$ is the vertical projection of the element E.

If through the point a, another line O be drawn parallel to V and making with H an angle equal to the angle made by N, it will generate when revolved about the axis M, the same hyperboloid. A horizontal plane whose vertical trace is VL, will cut N and O in the points d and e. As the generatrices N and O revolve, the points d and e will generate the same circle. Likewise, the two points in which any horizontal plane intersects N and O will generate the same circle; therefore, the two generations will give the same surface. As the surface may be generated by two different right lines, it follows that through any point of the surface, two elements may be drawn.

If the first generatrix remains fixed in its initial position N, and the second generatrix O be revolved, the point e will at some time in its motion coincide with d, and O in this position will be an element of the second generation intersecting the first generatrix in d. In the same way O can be revolved until any other point in it coincides with a point in N, giving another element of the second generation intersecting N. But any element of the first generation may be taken as the first generatrix; therefore, each element of one generation will intersect all the elements of the other generation.

But three rectilinear directrices, no two of which are parallel, are sufficient to determine the motion of a generatrix. Hence, if any three elements of one generation be taken as directrices, and an element of the other generation be moved so as always to touch them, the same surface will be generated.

Any warped surface with three rectilinear directrices, no two of which are parallel, is a *hyperboloid of one nappe*. The *hyperboloid of revolution of one nappe*, the one constructed in Fig. 81, may be defined as the warped surface generated by a right line moving so as to touch three other right lines equally distant from a fourth (the axis), the distances being measured in a plane perpendicular to the fourth, the directrices always making equal angles with this plane.

This hyperboloid of revolution is the only one employed in the arts.

PROB. 157. To construct a plane tangent to a hyperboloid of revolution at any point of the surface, and to find a meridian curve of the surface.

In Fig. 81, assume t^h as the horizontal projection of a point on the surface. A^h and B^h drawn through t^h tangent to $m^ha^hn^h$, are the horizontal projections of two elements through t. The plane X passed through A and B is the required tangent plane.

A meridian curve of the surface is constructed by passing a plane through the axis parallel to V, and finding its intersection with the elements. The horizontal trace of this plane is HU, and an element E intersects it in the point r, which is one point in the meridian curve. If through r^h a line C^h be drawn tangent to $m^ha^hn^h$, it will be the horizontal trace of an element C which intersects the plane U in the point $(r^h - s^v)$. The points r^v and s^v are seen to be equally distant from m^vn^v. Thus it is shown that for every point as r^v on the curve on one side of m^vn^v, there is a point, as s^v on the opposite side, equally distant from m^vn^v, and therefore m^vn^v is an axis of symmetry.

A horizontal plane whose vertical trace is VL intersects N in d, and d^hg^h is the horizontal projection of the circle generated by this point, and g is the point of intersection of the meridian plane and this circle. The distance $d^vg^v = M^hd^h - a^hd^h$ is the difference between the hypothenuse and altitude of a right triangle having M^ha^h for its base. If a point of the curve is taken farther from m^vn^v than g^v is, the base of the corresponding triangle remains of the same length, while both the hypothenuse and altitude increase. If b = base, y = altitude, and z = hypothenuse, then $z^2 - y^2 = b^2$, and

$$z - y = \frac{b^2}{z + y} \quad . \; . \; . \quad (1).$$

In (1), as b is constant, $z - y$ will diminish toward zero as a limit, as z and y increase indefinitely, and $z - y$ is the distance between the line N and the curve measured on a horizontal line. Hence, N is an asymptote to the curve. Likewise it might be shown that O is another asymptote.

The element E intersects N in p and O_1 in o. The vertical projection E^v must be tangent to the curve $r^v n^v s^v$ at r^v, for the element has but one point in common with the curve, and no point of the element can be vertically projected on the right of the curve. As $r^h o^h = r^h p^h$, then $r^v o^v = r^v p^v$, or the point of contact r^v bisects the tangent between the asymptotes. It is proved in Analytical Geometry that this is a property peculiar to the hyperbola. Therefore the meridian of a hyperboloid of revolution is a hyperbola. It is now evident that the surface may be generated by revolving a hyperbola about its conjugate axis. The surface receives its name from this method of generation.

51. The *helicoid* is a warped surface which may be generated by a right line moving so as to intersect a helix and its axis, and making always a constant angle with the axis.

PROB. 158. To construct elements of a helicoid and to pass a plane tangent to the surface at any point.

In Fig. 83, the axis M is taken perpendicular to H, and N is the generatrix in a position parallel to V. As the generatrix moves around the axis and also in the direction of its length, each point of the generatrix will generate a helix. The helix generated by the point a is ajk.

To construct an element, the horizontal projection E^h passing through M^h is first assumed. The point l is the intersection of the element with the helix. The distance $l^v x$, from l^v to GL, is laid off from b^v to y, along the vertical projection of the axis. Then the line $l^v y$ will be the required vertical projection E^v.

To pass a plane tangent to the surface at any point as l. The tangent plane must contain the element E, which passes through l, and also the tangent to the helix at that point. The tangent to the helix at l is T. The plane X, which contains the lines E and T, is the required tangent plane.

The elements intersect H in the curve $a^h m^h n^h$, which is the spiral of Archimedes.

When the elements of a helicoid are perpendicular to the axis, the surface is called a ***right helicoid.*** If the elements are oblique to the axis, the surface is called an ***oblique helicoid.***

The curved surface of the threads of an ordinary V-screw is an oblique helicoid. The right helicoid is the working surface of the square-threaded screw, and of the common screw propeller.

Art. 22. Additional Problems on Surfaces.

52. PROB. 159. To construct elements of a warped surface with any three rectilinear directrices.

Analysis. Through any assumed point of the first directrix a plane may be passed through the second directrix. The intersection of this plane with the third directrix will be a point, which connected with the assumed point, gives a line which intersects all three directrices, and hence is an element of the surface.

PROB. 160. To construct elements of a warped surface with three linear directrices, one or more being curved lines.

Analysis. Through any assumed point of the first directrix and different points of the second directrix, lines may be passed. These lines form, in general, a conical surface having its vertex at the assumed point. The intersection of this cone with the third directrix will be a point, which connected with the assumed point, gives a line which intersects all three directrices, and hence is an element of the surface.

The construction of an element, when the directrices are all curvilinear, is seen in Fig. 84.

53. A *conoid* is a warped surface with a plane director and two linear directrices, one being a right line and the other a curve. A *right conoid* is one whose rectilinear directrix is perpendicular to the plane director. This directrix is called the *line of striction.*

PROB. 161. To construct a conoid and a plane tangent to the surface at any point.

Analysis. If a plane be passed through an assumed point of the rectilinear directrix parallel to the plane director, it will intersect the curved directrix in a point or points which connected with the assumed point will give one or more elements of the surface. The construction will be simplified by taking the curvilinear directrix in *H*.

A plane, tangent to the surface at any point, will contain the rectilinear element through this point. If the curvilinear directrix is in *H*, the horizontal trace of this tangent plane will be tangent to the curved directrix at the foot of the element of contact.

54. The *cylindroid* is a warped surface having a plane director and two curvilinear directrices.

This surface has been used for the soffit of a descending arch.

PROB. 162. To construct elements of a cylindroid.

55. The *warped arch* or *cow's horn* is a warped surface having one rectilinear and two curvilinear directrices; the curved directrices are equal circles in parallel planes, and the straight directrix is perpendicular to the planes of the circles, and passes through the middle point of the line joining their centers.

The soffit of the skew arch is frequently made to conform to this surface.

PROB. 163. To construct elements of a warped arch.

The elements may be constructed as in Prob. 160. The construction will be simplified by taking the circular directrices parallel to *V*.

56. The *elliptical hyperboloid* is a warped surface having as directrices three similar ellipses, one of these ellipses being midway between two larger equal ellipses, all having their corresponding axes parallel, and their centers in a right line perpendicular to their planes.

PROB. 164. To construct an elliptical hyperboloid, and to pass a plane tangent to the surface at any point.

The surface may be constructed as in Prob. 160. The construction will be simplified by taking one of the larger ellipses in *H*.

A symmetrical construction, such as is seen in Fig. 85, may be made as follows: An ellipse is drawn in H as in Prob. 97, by first taking equidistant points on one of the concentric circles. A line connecting any two of the corresponding points, found on the ellipse, may be assumed, as the horizontal projection of an element, and the horizontal projection of any other element will connect two points on the ellipse corresponding to two points on the circle at the same distance from each other as the first two. The height above H of the plane of the upper base may now be assumed, and the vertical trace of this horizontal plane drawn. The vertical projections of the elements may now be readily constructed.

This is a doubly-ruled surface, and therefore through any point of it two elements may be drawn. A tangent plane to the surface at any point is determined by the two elements that may be passed through this point.

57. The *Serpentine* is a double curved surface that may be generated by a circle moving about an axis, so that it is always in the same plane with the axis, its center describing a helix. It may also be generated by a sphere whose center moves in a helix. The serpentine may be regarded as the envelope of the generating sphere.

The serpentine and the torus are sometimes called tubular surfaces.

Prob. 165. To construct the projections of a serpentine, and to pass a plane tangent to the surface at any point.

Analysis. The projections of a helix are first drawn. Then a series of circles whose diameters are equal to the diameter of the generating sphere are drawn with their centers on the vertical projection of the helix, and a corresponding series with their centers on the horizontal projection of the helix. The lines enveloping the series of circles in each projection will be lines of visible contour.

To pass a plane tangent to the surface at any point. A horizontal plane through the assumed point, and a plane through the point and axis, will cut circles from the surface. The right lines tangent to these circles at the given point will determine the required tangent plane.

58. A *right* hyperbolic paraboloid is one in which the plane directors of the two generations are perpendicular. A *line of striction* in a warped surface is the shortest line connecting consecutive elements. In the hyperbolic paraboloid it is that element of one generation which is perpendicular to the plane director of the other generation.

PROB. 166. To construct a right hyperbolic paraboloid and a line of striction.

The construction will be simplified by taking *H* and *V* as the two plane directors, and a line in *H* as one of the directrices of one generation, and a line in *V* as one of the directrices of the other generation.

PROB. 167. To construct the projections of a developable helicoid, the projections of whose axis make given angles with *GL*.

PROB. 168. To inscribe a sphere in a given triangular pyramid.

PROB. 169. To pass a plane through the point *a* in Fig. 86, tangent to the spheres whose centers are *b* and *c*.

PROB. 170. To pass a plane so as to cut a parabola or a hyperbola from a hyperbolic paraboloid.

Any plane parallel to the line of intersection of the two plane directors will cut a parabola, and any plane oblique to this intersection will cut a hyperbola from the surface.

PROB. 171. To find the intersection of an oblique plane with an oblique cone, and to develop the cone and the curve of intersection.

Analysis. To develop the cone: If an auxiliary sphere be passed having its center at the vertex of the cone, it will cut the cone in a curve all of whose points will be at the same distance from the vertex. Hence, when the cone is developed this curve will develop into an arc of a circle whose radius is equal to the radius of the sphere. On this arc the curve of intersection may be developed, and the developed position of any element is found by connecting the developed position of its intersection with the sphere and the vertex. The developed position of any point in the required intersection is obtained by getting the development of the element containing the point, and measuring along it the true distance from the vertex to the point.

59. A plane passed through the axis of an oblique cylinder or cone having a central curve for its base, and perpendicular to the base, is called the *principal plane.*

Sub-contrary sections of such a cylinder or cone are cut by two planes perpendicular to the principal plane, and making equal angles with the plane of right section.

PROB. 172. To pass two planes cutting sub-contrary sections from an oblique cylinder or cone with a circular base.

PROB. 173. To find the intersection of a plane and a helicoid, and to draw a tangent to the curve of intersection.

Analysis. Auxiliary planes may be passed through the axis of the helicoid. Each auxiliary plane will cut a rectilinear element from the helicoid and a right line from the given plane, whose intersection will be one point of the required curve.

PROB. 174. Fig. 87 shows the projections of a bolt head, partly square and partly conical; and Fig. 88 shows a hexagonal bolt head with its end turned to a spherical shape. To find the curve e^vf^v in each.

PROB. 175. To find the intersection of a plane and any of the curved surfaces that have been given.

PROB. 176. To find when a line, whose projections are given, intersects any given curved surface.

PROB. 177. To find the intersection of an oblique circular cylinder, whose axis makes given angles with the planes of projection, with any of the curved surfaces that have been given.

PROB. 178. To find the intersection of a given oblique prism with any of the curved surfaces that have been given.

PROB. 179. To construct the two projections of a right groined vault, one foot in thickness, when the cylindrical axes are in the same plane parallel to *H*, and equally inclined to *V*.

Analysis. A right groined vault is formed by the intersection of two equal right circular semi-cylindrical shells. The axes of the semi-cylindrical shells are at right angles to each other. Each shell is the volume between two concentric semi-cylinders differing one foot in radius, and standing on a horizontal plane through its axis.

The groined vault or arch is much used in masonry constructions, especially in architecture.

Prob. 180. In Fig. 90 are shown the plan, front and end elevations of a round rod turned in an ordinary lathe from a rectangular bar. It is required to find h^h-g^h and e^v-f^v, the projections of the lines of visible contour of this surface of revolution connecting the round rod and rectangular bar.

Prob. 181. To pass a plane tangent to a helicoid and parallel to a given right line.

Analysis. Let the helicoid be given as in Fig. 83. A right circular cone with any point of the given line as a vertex, whose elements make the same angle with H as the elements of the helicoid, is constructed. Then a plane passed through this line tangent to the cone, will be parallel to the required plane.

Prob. 182. To pass a plane ~~tangent to a helicoid~~, and perpendicular to a given line.

Analysis. A cone of revolution is constructed with any point of the axis as a vertex, whose elements make with H the same angle as the elements of the helicoid. Then a plane passed through the vertex of this cone perpendicular to the given line, will, if the construction be possible, cut from the cone two elements each of which is parallel to an element of the helicoid, and having the same horizontal projection. If a plane be passed through either of these elements parallel to the auxiliary plane, it will be tangent to the surface, and perpendicular to the given line.

Prob. 183. To pass a plane tangent to two oblique cones having a common vertex, the bases being in the planes of projection.

Prob. 184. To construct the projections of one coil of a screw conveyor of the form of a developable helicoid. The diameter of the inner helix being 6″, of the outer 12″, pitch 20″.

PROB. 185. To pass a plane through a point without the surface, and tangent to any one of the given double curved surfaces of revolution.

Analysis. Through a point without the surface of any double curved surface of revolution, an infinite number of tangent planes may be passed. If the axis of revolution is perpendicular to *H*, two such tangent planes may be constructed perpendicular to *V*, having their vertical traces through the vertical projection of the given point, and tangent to the vertical projection of the principal meridian.

PROB. 186. The right section of the outer surface of a main sewer is shown in Fig. 90. A tributary cylindrical sewer of 1′ outside diameter empties into the main sewer at an angle of 60°, the axes of the sewers intersecting in the horizontal plane through the point *a*. To find the curve of intersection.

PROB. 187. To construct a plane through a given line, whose projections are given, and tangent to a surface of revolution by means of an auxiliary hyperboloid of revolution of one nappe.

Analysis. An auxiliary hyperboloid of revolution of one nappe is generated by revolving the given line about the axis of the given surface. The given line is an element of the auxiliary surface, and a plane through this element tangent to the given surface, will also be tangent to the hyperboloid at some point in the element. A plane through the common axis will be a meridian plane of both surfaces, and the tangent plane is perpendicular to the meridian plane at the point of contact on the given surface. Hence, the common meridian plane passed perpendicular to the common tangent plane, contains the points of contact on both surfaces, and intersects the common tangent plane in a line which is tangent to both meridian curves at the points of contact of the tangent plane. This line, tangent to the meridian curves, and the given line, determine the required tangent plane.

If the axis of revolution be taken perpendicular to *H*, a common tangent to the meridian curves parallel to *V* will give the revolved positions of the points of contact.

Prob. 188. To design the steps and the balustrade and its supports for a spiral staircase, to connect one floor of a building with the floor above. The staircase vestibule is 12 feet square and 21 feet high. The staircase begins at the middle point of one side and winds through an arc of 360° in making the ascent. All of the steps are to run to the side walls. The well-hole in the center is in the form of a right vertical circular cylinder. Each step is to be 7 inches in height, and the shortest one is to be 3 feet long. The balustrade is to be 3 feet high, and runs from a newel post at the bottom to the top.

Prob. 189. To construct two hyperbolic paraboloids tangent to each other along a common element.

Two surfaces are said to *raccord* along a common line when they have a common tangent plane at any point along this line.

Analysis. Any two warped surfaces will raccord along a common element when they have common tangent planes at two points of this element, and also a common plane director. So through any element of a given hyperbolic paraboloid an infinite number of hyperbolic paraboloids may be passed which will be tangent to the first surface all along this element. Let M and N be the directrices, and ab an element of a given hyperbolic paraboloid, a and b being the intersections of the element with M and N respectively. The tangent plane to the given surface at a, which is determined by lines M and ab, and the tangent plane at b, determined by N and ab, may be taken as two common tangent planes. Any line in plane (M, ab) through a, and any other line in plane (N, ab) through b, may be taken as directrices of the required hyperbolic paraboloid. The required tangent hyperbolic paraboloid may then be constructed with these two lines as directrices, and with the same plane director as the first surface.

Prob. 190. To construct two hyperboloids of revolution of one nappe designed to work together tangentially.

Analysis. Any two warped surfaces will raccord along a common line when they have common tangent planes at three points of this line. Let M, N and O be the three rectilinear directrices, and abc a rectilinear element of the given hyperboloid of one nappe, a, b and c being the intersections of the element with the directrices M, N and O respectively. At the point a any line M' in the plane of the lines M and abc may be taken as a directrix for the second surface. Similarly, two other directrices N' and O' may be assumed; and the lines M', N' and O' will be directrices of a hyperboloid of one nappe tangent to the given one along the element abc. If M', N' and O' are all parallel to one plane, the second surface will be a hyperbolic paraboloid.

The lines of the teeth of wheels in hyperboloidal gearing are elements of two tangent hyperbolic paraboloids.

Prob. 191. In a spherical triangle, two sides and an angle opposite one of them are given, to find the other parts.

Analysis. In the spherical pyramid of which the given triangle is the base, the faces and diedral angles are measured respectively by the sides and angles of the given triangle. Therefore, a graphical solution of the spherical triangle will be found when the corresponding triedral angle is constructed. Hence, it is required to construct a triedral angle when two face angles and a diedral angle opposite one of them are given.

In Fig. 91, let the sides of the given triangle be a, b and c, and opposite angles α, β and γ. Likewise, let the faces of the required triedal angle be a, b and c, opposite angles α, β and γ, and edges A, B and C. Let it be assumed that a, b and α are given.

The face b is taken in H, the edge C which is between the given faces being placed perpendicular to GL. Assuming the point o as the vertex of the triedral angle, $A^h o C^h$ represents the face b in its true size.

B_1, drawn at an angle equal to a with C^h is the position of the third edge after it is revolved about C into H.

The face c will lie in a plane whose horizontal trace is A^h and which makes with H the angle α. VD is the vertical trace of this plane.

After the counter-revolution of B_1, the vertical trace of B is found at the intersection of VD, and the arc described by point m. The edge B connects B_v and o.

From the projections of the triedral angle o-ABC, the parts c, γ and β can be readily found.

PROB. 192. In a spherical triangle, two angles and a side opposite one are given, to find the other parts.

PROB. 193. In a spherical triangle, two sides and the included angle are given, to find the other parts.

PROB. 194 In a spherical triangle, the three sides are given, to find the three angles.

60. If the eye of an observer and a point be situated on opposite sides of a surface and a right line be passed connecting them, the intersection of the line with the surface may be called the *linear perspective* of the point. In perspective drawing the position of the eye is called the *point of sight*, the surface is the *picture surface*, and the line is the *visual ray*. The perspective of any right line is the line connecting the perspectives of two points of the given line The perspective of any object is determined by the perspectives of the lines on the body.

PROB. 195. To construct the perspective of a polyedron in the third angle, assuming that V is the picture plane, and taking the point of sight in the fourth angle.

Place the body in the third angle so that its projections may be readily obtained. Assume the point of sight at some distance in front of V to the right or left of the body and a little above it. The perspective of any point of the body may be found by drawing the projections of the visual ray from this point and getting its intersection with V. By connecting the perspectives of points on the body, the perspectives of all the visible edges may be obtained.

Catalogue of the Scientific Publications and Importations of D. Van Nostrand Company, 23 Murray Street and 27 Warren Street, New York.

A. B. C. CODE. **(See Clausen-Thue.)**

ABBOTT, A. V. **The Electrical Transmission of Energy.** A Manual for the Design of Electrical Circuits. *Second Edition, Revised.* Fully illustrated. 8vo, cloth..................$4 50

ABBOT, Gen'l HENRY L. **The Defence of the Seacoast** of the United States. Lectures delivered before the U. S. Naval War College. 8vo, red cloth..........................$2.00

ADAMS, J. W. **Sewers and Drains for Populous Districts.** Embracing Rules and Formulas for the dimensions and construction of works of Sanitary Engineers. 8vo, cloth..........$2.50

ADDYMAN, FRANK T. **Practical X Ray Work.** Part I, Historical. Part II, Apparatus and its Management. Part III, Practical X Ray Work. Illustrated with twelve plates from Photographs. 8vo, cloth, illustrated.......................... *net,* $4.00

A. 1 CODE. **(See Clausen-Thue.)**

AIKMAN, C. M., Prof. **Manures and the Principles** of Manuring. 8vo, cloth....................................$2.00

ALEXANDER, J. H. **Universal Dictionary of Weights** and Measures, Ancient and Modern, reduced to the Standards of the United States of America. *New Edition, enlarged.* 8vo, cloth..$3.50

ALEXANDER, S. A. **Broke Down: What Should I Do?** A Ready Reference and Key to Locomotive Engineers and Firemen, Round House Machinists, Conductors, Train Hands and Inspectors. With 5 folding plates. 12mo, cloth...........................$1.50

ANDERSON, GEO. L., A. M. **(Captain of U. S. Artillery.)** Handbook for the use of Electricians in the operation and care of Electrical Machinery and Apparatus of the United States Seacoast Defenses. Prepared under the direction of the Lieutenant-General Commanding the Army. With tables, diagrams and illustrations. 8vo, cloth, illustrated..................................$3.00

ANDERSON, J. W. The Prospector's Handbook; A Guide for the Prospector and Traveller in search of Metal-bearing, or other Valuable Minerals. *Eighth Edition, revised.* 8vo, cloth, $1.50

ANDERSON, WILLIAM. On the Conversion of Heat into Work. A Practical Handbook on Heat-Engines. *Third Edition* Illustrated. 12mo, cloth $2.25

ANDÉS, LOUIS. Vegetable Fats and Oils, Their Practical Preparation, Purification and Employment for various Purposes. Their Properties, Adulteration and Examination, A Hand Book for Oil Manufacturers and Refiners, Candle, Soap and Lubricating Oil Manufacturers and the Oil and Fat Industry in general. Translated from the German. With 94 illustrations. 8vo, cloth...... ...$4.00

—— Animal Fats and Oils. Their Practical Production, Purification and Uses for a great variety of purposes, their Properties, Falsification and Examination. A Hand Book for Manufacturers of Oil and Fat Products, Soap and Candle Makers, Agriculturists, Tanners, etc. Translated by Charles Salter. With 62 illustrations. 8vo, cloth.................................... *net,* $4.00

—— Drying Oils, Boiled Oil, and Solid and Liquid Driers. A practical work for manufacturers of Oils, Varnishes, Printing Inks, Oil-cloth and Linoleum, Oil-cakes, Paints, etc. 8vo, cloth, illustrated $5.00

—— Iron Corrosion, Anti-fouling and Anti-corrosive Paints. Translated from the German by Charles Salter. Illustrated with engravings and half-tone cuts. 8vo, cloth, illustrated..*net.* $4.00

ARNOLD, Dr. R. Ammonia and Ammonium Compounds. A Practical Manual for Manufacturers, Chemists, Gas Engineers and Drysalters. *Second Edition.* 12mo, cloth........ $2.00

ARNOLD, E. Armature Windings of Direct Current Dynamos. Extension and Application of a General Winding Rule. Translated from the original German by Francis B. DeGress, M. E. With numerous illustrations. 8vo, cloth..................... $2.00

Art of Dyeing Wool, Silk and Cotton. Translated from the French of M. Hellott, M. Macquer and M. Le Pileur D'Apligny. First published in English in 1789. 8vo, cloth, illustrated... .... *net,* $2.00

ATKINSON, Prof. A. A. (*Ohio University.*) **Electrical** and Magnetic Calculations, for the use of Electrical Engineers and Artisans, Teachers, Students and all others interested in the Theory and Application of Electricity and Magnetism. 8vo, cloth, illustrated .... *net,* $1.50

ATKINSON, PHILIP. The Elements of Electric Lighting, including Electric Generation, Measurement, Storage, and Distribution. *Tenth Edition.* Fully revised and new matter added. Illustrated. 12mo, cloth....................................$1.50

—— **The Elements of Dynamic Electricity and Magnetism.** *Third Edition.* 120 illustrations. 12mo, cloth......$2.00

——— **Power Transmitted by Electricity and its Application** by the Electric Motor, including Electric Railway Construction. Illustrated. 12mo, cloth. *Third edition fully revised, new matter added*..$2.00

—— **Elements of Static Electricity,** with full description of the Holtz and Topler Machines, and their mode of operating. Illustrated. 12mo, cloth....................................$1.50

AUCHINCLOSS, W. S. Link and Valve Motions Simplified. Illustrated with 29 woodcuts and 20 lithographic plates, together with a Travel Scale, and numerous useful tables. *Fourteenth Edition, revised.* 8vo, cloth...............................$2.00

AXON, W. E. A. The Mechanic's Friend. A Collection of Receipts and Practical Suggestions relating to Aquaria, Bronzing, Cements, Drawing, Dyes, Electricity, Gilding, Glass-working, Glues, Horology, Lacquers, Locomotives, Magnetism, Metal-working, Modelling, Photography, Pyrotechny, Railways, Solders, Steam-Engine, Telegraphy, Taxidermy, Varnishes, Waterproofing, and Miscellaneous Tools, Instruments, Machines, and Processes connected with the Chemical and Mechanic Arts. With numerous diagrams and woodcuts. 12mo, cloth, illustrated......................................$1.50

AYRTON, W. E. (M. I. C. E.) **Practical Electricity: a** Laboratory and Lecture course for the first year students of Electrical Engineering, based on the Internatianal Definitions of the Electrical Units. Vol. I, Current, Pressure, Resistance, Energy, Power and Cells. Completely re-written and containing many figures and diagrams. 12mo, cloth $2.00

AYRTON, HERTHA. The Electrical Arc. With numerous figures, diagrams and plates. 8vo, cloth, illustrated....$5.00

BACON, F. W. A Treatise on the Richards Steam-Engine Indicator, with directions for its use. By Charles T. Porter. Revised, with notes and large additions as developed by American practice; with an appendix containing useful formulæ and rules for engineers. Illustrated. *Fourth Edition.* 12mo, cloth........$1.00

BADT, F. B. New Dynamo Tenders Hand-Book. With 140 illustrations. 18mo, cloth.........................$1.00

—— **Bell Hangers' Hand-Book. With 97 illustrations.** *Second Edition.* 18mo, cloth...............................$1.00

BADT, F. B. Incandescent Wiring Hand-Book. With 35 illustrations and five tables. *Fifth Edition.* 18mo, cloth,...$1.00

—— **Electric Transmission Hand-Book. With 22 Illustrations** and 27 Tables. 18mo, cloth $1.00

BAKER, M. N. Potable Water and Methods of Detecting Impurities. 16mo. (*Van Nostrand's Science Series.*).. .50

BALCH, COL. GEO. T. Methods of Teaching Patriotism in the Public Schools. 8vo, cloth........................ $1.00

BALE, M. P. Pumps and Pumping. A Hand Book for Pump Users. 12mo, cloth................................. $1.50

BARBA, J. The Use of Steel for Constructive Purposes. Method of Working, Applying, and Testing Plates and Bars. With a Preface by A. L. Holley, C.E. 12mo, cloth.................. $1.50

BARKER, ARTHUR H. Graphic Methods of Engine Design. Including a Graphical Treatment of the Balancing of Engines. 12mo, cloth.. $1.50

BARNARD, F. A. P. Report on Machinery and Processes of the Industrial Arts and Apparatus of the Exact Sciences at the Paris Universal Exposition, 1867. 152 illustrations and 8 folding plates. 8vo, cloth.. $5.00

BARNARD, JOHN H. The Naval Militiaman's Guide. Full leather, pocket form.................................. $1.25

BARRUS, GEO. H. Boiler Tests: Embracing the results of one hundred and thirty seven evaporative tests, made on seventy-one boilers, conducted by the author. 8vo, cloth $3.00

—— **Engine Tests; embracing the results of over one** hundred feed-water tests and other investigations of various kinds of steam engines, conducted by the author. With numerous figures, tables and diagrams. 8vo, cloth, illustrated $4.00
The two books sent prepaid for $6.00

BARWISE, SIDNEY, M. D., London. The Purification of Sewage. Being a brief account of the Scientific Principles of Sewage Purification and their Practical Application. 12mo, cloth. Illustrated.. $2.00

—— **The Bacterial Purification of Sewage. Being a** Practical Account of the various Modern Biological Methods of Purifying Sewage. With plates and diagrams. 8vo, cloth, illustrated. ....*net.* $2.50

BAUMEISTER, R. The Cleaning and Sewerage of Cities. Adapted from the German with permission of the author. By J. M. Goodell, C. E. *Second edition, revised and corrected, together with an additional appendix.* 8vo, cloth. Illustrated. . $2 00

BEAUMONT, ROBERT. Color in Woven Design. With 32 colored Plates and numerous original illustrations. Large, 12mo.. $7.50

BEECH, FRANKLIN. Dyeing of Cotton Fabrics. A Practical Handbook for the Dyer and Student. Containing numerous recipes for the production on Cotton Fabrics of all kinds, of a great range of colours, thus making it of great service in the dye house, while to the student it is of value in that the scientific principles which underlie the operations of dyeing are clearly laid down. With 44 illustrations of Bleaching and Dyeing Machinery. 8vo, cloth, illustrated .... *net.* $3.00

BECKWITH, ARTHUR. Pottery. Observations on the Materials and Manufacture of Terra-Cotta, Stoneware, Fire-Brick, Porcelain, Earthenware, Brick, Majolica, and Encaustic Tiles. 8vo, paper. *Second Edition*................ .... .60

BEGTRUP, JULIUS, M. E. The Slide Valve and its Functions. With Special Reference to Modern Practice in the United States. With numerous diagrams and figures. 8vo, cloth, illustrated. .... *In Press.*

BERNTHSEN, A. A Text-Book of Organic Chemistry. Translated by George M'Gowan, Ph.D. *Fourth English Edition.* Revised and extended by author and translator. Illustrated. 12mo, cloth $2.50

BERSCH Dr. JOSEF. Manufacture of Mineral and Lake Pigments; containing directions for the manufacture of all artificial artists' and painters' colours, enamel colours, soot and metallic pigments. A text-book for Manufacturers, Merchants, Artists and Painters. *Translated from the second revised edition* by Arthur C. Wright, M. A. 8vo, cloth, illustrated.................... *net.* $5.00

BERTIN, L. E. Marine Boilers: Their Construction and Working, dealing more especially with Tubulous Boilers. Translated by Leslie S. Robertson, Assoc. M. Inst., C. E., M. I. Mech. E., M. I. N. A., containing upward of 250 illustrations. Preface by Sir William White, K. C. B., F. R. S., Director of Naval Construction to the Admiralty, and assistant Controller of the Navy. 8vo, cloth. Illustrated. 437 pp... $7.50

BIGGS, C. H. W. First Principles of Electricity and Magnetism. A book for beginners in practical work, containing a good deal of useful information not usually to be found in similar books. With numerous tables and 343 diagrams and figures. 12mo, cloth, illustrated................ .... $2.00

BINNS, CHAS. F. Manual of Practical Potting. Compiled by Experts. *Third edition, revised and enlarged.* 8vo, cloth.. *net,* $7.50

BINNS, CHAS. F. Ceramic Technology ; being some aspects of Technical Science as applied to Pottery Manufacture. 8vo, cloth...*net,* $5.00

BLAKE, W. P. Report upon the Precious Metals. Being Statistical Notices of the principal Gold and Silver producing regions of the world, represented at the Paris Universal Exposition. 8vo, cloth.. $2.00

BLAKESLEY, T. H. Alternating Currents of Electricity. For the use of Students and Engineers. *Third Edition, enlarged.* 12mo, cloth..$1.50

BLYTH, A. WYNTER, M.R.C.S., F.C.S. Foods: their Composition and Analysis. A Manual for the use of Analytical Chemists, with an Introductory Essay on the History of Adulterations, with numerous tables and illustrations. *Fourth Edition, revised and enlarged.* 8vo, cloth..$7.50

—— **Poisons: their Effects and Detection. A Manual** for the use of Analytical Chemists and Experts, with an Introductory Essay on the growth of Modern Toxicology. *Third Edition, revised and enlarged.* 8vo, cloth..................................$7.50

BODMER, G. R. Hydraulic Motors and Turbines For the use of Engineers, Manufacturers, and Students. *Third Edition, revised and enlarged.* With 192 illustrations. 12mo, cloth.. $5.00

BOILEAU, J. T. A New and Complete Set of Traverse Tables, Showing the Difference of Latitude and Departure of every minute of the Quadrant and to five places of decimals. 8vo, cloth.$5.00

BONNEY, G. E. The Electro-Platers' Hand Book. A Manual for Amateurs and Young Students on Electro-Metallurgy. 60 Illustrations. 12mo, cloth.................................$1.20

BOTTONE, S. R. Electrical Instrument Making for Amateurs. A Practical Handbook. With 48 illustrations. *Fifth Edition, revised.* 12mo, cloth.................................. .50

—— **Electric Bells, and all about them. A Practical** Book for Practical Men. With more than 100 illustrations. 12mo, cloth. *Fourth Edition, revised and enlarged*................. .50

—— **The Dynamo: How Made and How Used. A** Book for Amateurs. *Eighth Edition.* 12mo, cloth............$1.00

—— **Electro Motors: How Made and How Used. A** Hand Book for Amateurs and Practical Men. *Second Edition.* 12mo, cloth.. .75

BOURRY, EMILE. Treatises on Ceramic Industries ; a Complete Manual for Pottery, Tile and Brick Works. Translated from the French by Wilton P. Rix. With 323 figures and illustrations. 8vo, cloth, illustrated...........................*net,* $7.50

BOW, R. H. A Treatise on Bracing. With its application to Bridges and other Structures of Wood or Iron. 156 illustrations. 8vo, cloth...$1.50

BOWIE, AUG. J., Jun., M. E. A Practical Treatise on Hydraulic Mining in California. With Description of the Use and Construction of Ditches, Flumes, Wrought-iron Pipes and Dams; Flow of Water on Heavy Grades, and its Applicability, under High Pressure, to Mining. *Fifth Edition.* Small quarto, cloth. Illustrated... $5.00

BOWSER, Prof. E. A. An Elementary Treatise on Analytic Geometry. Embracing Plane Geometry, and an Introduction to Geometry of three Dimensions. 12mo, cloth. *Twenty-first Edition*...$1.75

—— **An Elementary Treatise on the Differential and** Integral Calculus. With numerous examples. 12mo, cloth. *Seventeenth Edition*.. $2.25

—— **An Elementary Treatise on Analytic Mechanics.** With numerous examples. 12mo, cloth. *Fourteenth Edition.* .$3.00

—— **An Elementary Treatise on Hydro-Mechanics.** With numerous examples. 12mo, cloth. *Fifth Edition*.......$2.50

—— **A Treatise on Roofs and Bridges. With Numerous** Exercises. Especially adapted for school use. 12mo, cloth. Illustrated...*net* $2.25

—— **Academic Algebra.** *Third Edition.* 12mo, cloth...$1.25

—— **College Algebra.** *Fourth Edition.* 12mo, cloth..... $1.75

—— **Elements of Plane and Solid Geometry. 12mo,** cloth. *Second Edition*.......................................$1.40

BRASSEY'S Naval Annual for 1902. Edited by John Leland With numerous full page diagrams, half-tone illus., and tables. 8vo, cloth, illustrated ....*net.* $6.00

BROWN, WM. N. The Art of Enamelling on Metal. With figures and illustrations. 12mo. cloth, illustrated........$1.00

—— **Handbook on Japanning and Enamelling, for** Cycles, Bedsteads, Tinware, etc. 12mo, cloth, illustrated..*net,* $1.50

—— **House Decorating and Painting. With numerous** illustrations. 12mo, cloth..............................*net,* $1.50

—— **History of Decorative Art. With Designs and** illustrations. 12mo, cloth..............................*net,* $1.25

—— **Principle and Practice of Dipping, Burnishing,** Lacquering and Bronzing Brass Ware. 12mo, cloth............$1.00

BROWN, WM. N. **Workshop Wrinkles for Decorators**, Painters, Paper Hangers and Others. 8vo, cloth...... ..$1.00

BUCHANAN, E. E. **Tables of Squares; containing** the square of every foot, inch and sixteenth of an inch between one sixteenth of an inch and fifty feet. For Engineers and Calculators. 16mo, oblong, cloth......................................$1.00

BURGH, N. P. **Modern Marine Engineering, applied** to Paddle and Screw Propulsion. Consisting of 36 colored plates, 259 practical woodcut illustrations, and 403 pages of descriptive matter. The whole being an exposition of the present practice of James Watt & Co., J. & G. Rennie, R. Napier & Sons, and other celebrated firms. Thick quarto, half morocco $10.00

BURT, W. A. **Key to the Solar Compass, and Surveyor's** Companion. Comprising all the rules necessary for use in the field; also description of the Linear Surveys and Public Land System of the United States, Notes on the Barometer, Suggestions for an Outfit for a Survey of Four Months, etc. *Seventh Edition.* Pocket size full leather..$2.50

CALDWELL, G. C., and A. A. BRENEMAN. **Manual** of Introductory Chemical Practice. For the use of Students in Colleges and Normal and High Schools. *Fourth Edition revised and corrected.* 8vo, cloth. Illustrated.....................$1.50

CAMPIN, FRANCIS. **On the Construction of Iron** Roofs. A Theoretical and Practical Treatise, with wood-cuts and Plates of Roofs recently executed. 8vo, cloth..................$2.00

CARTER, E. T. **Motive Power and Gearing for Electrical** Machinery. A Treatise on the Theory and Practice of the Mechanical Equipment of Power Stations for Electric supply and for Electric Traction. 8vo, cloth. Illustrated......................$5.00

CATHCART, PROF. WM. LEDYARD. *Columbia University.* Marine Engine Design..........................*In Press.*

—— **Machine Elements; Shrinkage and Pressure** Joints..*In Press.*

—— **Stationary Engine Design**........................*In Press.*

CHAMBER'S MATHEMATICAL TABLES, consisting of logarithms of Numbers 1 to 108,000, Trigonometrical, Nautical and other tables. *New Edition.* 8vo, cloth..................$1.75

CHARPENTIER, PAUL. **Timber; a Comprehensive** Study of Wood in all its Aspects; Commercial and Botanical. Showing the Different Applications and Uses of Timber in Various Trades, etc. Translated into English. 8vo, cloth, illustrated. 437 pp..*net,* $6.00

CHAUVENET, Prof. W. **New Method of Correcting** Lunar Distances, and Improved Method of Finding the Error and Rate of a Chronometer, by Equal Altitudes. 8vo, cloth........$2 00

CHRISTIE, W. WALLACE. Chimney Design and Theory. A Book for Engineers and Architects, with numerous half-tone illustrations and plates of famous chimneys. *Second edition, revised.* 8vo, cloth $3.00

—— Furnace Draft ; its Production by Mechanical Methods. A Handy Reference Book, with figures and tables. 16mo, limp cloth, illustrated......................................$0.50

CHURCH, JOHN A. Notes of a Metallurgical Journey in Europe. 8vo, cloth......................................$2.00

CLAPPERTON, GEO. Practical Paper-making ; a Manual for Paper-makers and Owners and Managers of Paper Mills, to which is appended useful tables, calculations, data, etc., with illustrations reproduced from micro-photographs. 12mo, cloth, illustrated......................................$2.50

CLARK, D. KINNEAR, C.E. A Manual of Rules, Tables and Data for Mechanical Engineers. Based on the most recent investigations. Illustrated with numerous diagrams. 1,012 pages. 8vo, cloth, *Sixth Edition*......................................$5.00
Half morocco......................................$7.50

—— Fuel; its Combustion and Economy, consisting of abridgements of Treatise on the Combustion of Coal. By C. W. Williams; and the Economy of Fuel, by T. S. Prideaux. With extensive additions in recent practice in the Combustion and Economy of Fuel, Coal, Coke, Wood. Peat, Petroleum, etc. *Fourth Edition.* 12mo, cloth.... ....$1.50

—— The Mechanical Engineer's Pocket Book of Tables, Formulæ, Rules and Data. A Handy Book of Reference for Daily Use in Engineering Practice. 16mo, morocco. *Second Edition*...................................... ....$3.00

—— Tramways; their Construction and Working, Embracing a comprehensive history of the system, with accounts of the various modes of traction, a description of the varieties of rolling stock, and ample details of Cost and Working Expenses. *Second Edition. Re-written and greatly enlarged, with upwards of* 400 *illustrations.* Thick 8vo, cloth............................$9 00

CLARK, JACOB M. A new System of Laying Out Railway Turn-outs instantly, by inspection from tables. 12mo, leatherette $1.00

CLAUSEN-THUE, W. The A B C Universal Commercial Electric Telegraphic Code; specially adapted for the use of Financiers, Merchants, Ship-owners, Brokers, Agent, etc. *Fourth Edition.* 8vo, cloth. $5.00

Fifth Edition of same......................................$7.00

CLAUSEN-THUE, W. The A1 Universal Commercial Electric Telegraphic Code. Over 1240 pp., and nearly 90,000 variations. 8vo, cloth..$7.50

CLEEMANN, THOS. M. The Railroad .Engineer's Practice. Being a Short but Complete Description of the Duties of the Young Engineer in the Prelimary and Location Surveys and in Construction. 4th ed., revised and enlarged. Illus. 12mo, cloth $1.50

CLEVENGER, S. R. A Treatise on the Method of Government Surveying as prescribed by the U. S. Congress and Commissioner of the General Land Office, with complete Mathematical, Astronomical and Practical Instructions for the use of the United States Surveyors in the field. 16mo, morocco $2.50

COFFIN, Prof. J. H. C. Navigation and Nautical Astronomy. Prepared for the use of the U. S. Naval Academy. *New edition.* Revised by Commander Charles Belknap. 52 woodcut illustrations. 12mo, cloth.................................*net,* $3.50

COLE, R. S., M. A. A Treatise on Photographic Optics. Being an account of the Principles of Optics, so far as they apply to Photography. 12mo, cloth. 103 illustrationsand folding plates.$2.50

COLLINS, JAS. E. The Private Book of Useful Alloys and Memoranda for Goldsmiths, Jewelers, etc. 18mo, cloth.... .50

COOPER, W. R., M. A. Primary Batteries ; their Construction and Use. With numerous figures and diagrams. 8vo, cloth, illustrated.......................................*net,* $4.00

CORNWALL, Prof. H. B. Manual of Blow-pipe Analysis, Qualitative and Quantitative. With a Complete System of Determinative Mineralogy. 8vo, cloth, with many illustrations..$2.50

COWELL, W. B. Pure Air, Ozone and Water; a Practical Treatise of their Utilization and Value in Oil, Grease, Soap, Paint, Glue and other Industries. With tables and figures. 12mo, cloth, illustrated.......................................*net.* $2.00

CRAIG, B. F. Weights and Measures. An account of the Decimal System, with Tables of Conversion for Commercial and Scientific Uses. Square 32mo, limp cloth......... .... .50

CROCKER, F. B. Electric Lighting. A Practical Exposition of the Art. For use of Engineers, Students, and others interested in the Installation or Operation of Electrical Plants. Vol. I. The Generating Plant. *Fourth Edition, revised.* 8vo, cloth, illustrated... $3.00

Vol. II. Distributing Systems and Lamps. *Second edition.* 8vo, cl., illustrated...$3.00

CROCKER, F. B., and S. S. WHEELER. The Practical Management of Dynamos and Motors. *Fifth Edition, (Eleventh thousand) revised and enlarged.* With a special chapter by H. A. Foster. 12mo, cloth, illustrated..............................$1.00

DAVIES, E. H. Machinery for Metalliferous Mines. A Practical Treatise for Mining Engineers, Metallurgists and Manufacturers. With upwards of 300 illustrations. 8vo, cloth......$5.00

—— D. C. A Treatise on Metalliferous Minerals and Mining. *Sixth edition, thoroughly revised and much enlarged* by his son. 8vo, cloth.................................*net,* $5.00

——MINING MACHINERY..............................*In Press.*

DAY, CHARLES. The Indicator and its Diagrams. With Chapters on Engine and Boiler Testing; Including a Table of Piston Constants compiled by W. H. Fowler. 12mo, cloth. 125 illustrations..$2.00

DENNY, G. A. Deep-level Mines of the Rand, and their future development, considered from the commercial point of view. With folding plates, diagrams and tables. 4to, cloth, illustrated.. *net,* $10.00

DERR, W. L. Block Signal Operation. A Practical Manual. Oblong, cloth. *Second Edition*....................$1.50

DIETERICH, KARL. Analysis of Resins, Balsams and Gum Resins; their Chemistry and Pharmacognosis. For the use of the Scientific and Technical Research Chemist. With a Bibliography. Translated from the German, by Chas. Salter. 8vo, cloth. ....*net,* $3.00

DIXON, D. B. The Machinist's and Steam Engineer's Practical Calculator. A Compilation of Useful Rules and Problems arithmetically solved, together with General Information applicable to Shop-Tools, Mill-Gearing, Pulleys and Shafts, Steam-Boilers and Engines. Embracing valuable Tables and Instruction in Screw-cutting, Valve and Link Motion, etc. *Third edition.* 16mo, full morocco, pocket form...$1.25

DODD, GEO. Dictionary of Manufactures, Mining, Machinery, and the Industrial Arts. 12mo, cloth..............$1.50

DORR, B. F. The Surveyor's Guide and Pocket Table Book. *Fifth Edition. Thoroughly revised and greatly extended.* With a second appendix up to date. 16mo, morocco flaps $2.00

DRAPER, C. H. An Elementary Text Book of Light, Heat and Sound, with Numerous Examples. *Fourth edition.* 12mo, cloth. Illustrated..$1.00

DRAPER, C. H. Heat and the Principles of Thermo-Dynamics. With many illustrations and numerical examples. 12mo, cloth..........$1.50

DUBOIS, A. J. The New Method of Graphic Statics. With 60 illustrations. 8vo, cloth..........$1.50

EDDY, Prof. H. T. Researches in Graphical Statics. Embracing New Constructions in Graphical Statics, a New General Method in Graphical Statics, and the Theory of Internal Stress in Graphical Statics. 8vo, cloth..........$1.50

—— Maximum Stresses under Concentrated Loads. Treated graphically. Illustrated. 8vo, cloth..........$1.50

EISSLER, M. The Metallurgy of Gold; a Practical Treatise on the Metallurgical Treatment of Gold-Bearing Ores, including the Processes of Concentration and Chlorination, and the Assaying, Melting and Refining of Gold. *Fifth Edition, revised and greatly enlarged.* Over 300 illustrations and numerous folding plates. 8vo, cloth..........$7.50

—— The Hydro-Metallurgy of Copper. Being an account of processes adopted in the Hydro-Metallurgical treatment of Cupriferous Ores, including the manufacture of Copper Vitriol. With chapters on the sources of supply of Copper and the Roasting of Copper Ores. With numerous diagrams and figures. 8vo, cloth, illustrated..........*net*, $4.50

—— The Metallurgy of Silver; a Practical Treatise on the Amalgamation, Roasting and Lixivation of Silver Ores, including the Assaying, Melting and Refining of Silver Bullion. 124 illustrations. *Second Edition, enlarged.* 8vo, cloth.......... $4.00

—— The Metallurgy of Argentiferous Lead; a Practical Treatise on the Smelting of Silver-Lead Ores and the Refining of Lead Bullion. Including Reports on Various Smelting Establishments and Descriptions of Modern Smelting Furnaces and Plants in Europe and America. With 183 illustrations. 8vo, cloth......$5.00

—— Cyanide Process for the Extraction of Gold and its Practical Application on the Witwatersrand Gold Fields in South Africa. *Second edition enlarged.* Illustrations and folding plates. 8vo, cloth..........$3.00

—— A Hand-book on Modern Explosives, being a Prac-tical Treatise on the Manufacture and use of Dynamite, Gun Cotton, Nitro-Glycerine and other Explosive Compounds, including the manufacture of Collodion-cotton, with chapters on explosives in practical application. *Second Edition, enlarged with* 150 *illustrations.* 12mo, cloth..........$5.00

ELIOT, C. W., and STORER, F. H. A Compendious Manual of Qualitative Chemical Analysis. Revised with the co-operation of the authors, by Prof. William R. Nichols. Illustrated. *Twentieth Edition, newly revised by Prof. W. B. Lindsay.* 12mo, cloth ....*net* $1.25

ELLIOT, Maj. GEO. H. European Light-House Systems. Being a Report of a Tour of Inspection made in 1873. 51 engravings and 21 woodcuts. 8vo, cloth $5.00

ELLISON, LEWIS M. Practical Application of the Indicator. With reference to the Adjustment of Valve Gear on all styles of Engines. *Second Edition, revised.* 8vo, cloth, 100 illustrations..$2.00

ERFURT, JULIUS. Dyeing of Paper Pulp; a practical treatise for the use of paper-makers, paper-stainers, students and others. With illustrations and 157 patterns of paper dyed in the pulp, with formulas for each. Translated into English and edited, with additions, by Julius Hübner, F. C. S. 8vo, cloth, illustrated. .*net.* $7.50

EVERETT, J. D. Elementary Text-Book of Physics. Illustrated. *Seventh Edition.* 12mo, cloth...................$1.50

EWING, Prof. A. J. The Magnetic Induction in Iron and other metals. *Third edition, revised.* 159 illustrations. 8vo, cloth..$4 00

FAIRIE, JAMES, F. G. S. **Notes on Lead Ores; their** Distribution and Properties. 12mo, cloth.....................$1.00

—— **Notes on Pottery Clays; the Distribution, proper**ties, Uses and Analysis of Ball Clays, China Clays and China Stone. With tables and formulae. 12mo, cloth.......................$1.50

FANNING, J. T. A Practical Treatise on Hydraulic and Water-Supply Engineering. Relating to the Hydrology, Hydrodynamics, and Practical Construction of Water-Works in North America. 180 illustrations. 8vo, cloth. *Fifteenth Edition, revised, enlarged, and new tables and illustrations added.* 650 pages..$5.00

FISH, J. C. L. Lettering of Working Drawings. Thirteen plates, with descriptive text. Oblong, 9x12½, boards......$1.00

FISKE, Lieut. BRADLEY A., U.S.N. Electricity in Theory and Practice; or, The Elements of Electrical Engineering. *Eighth Edition.* 8vo, cloth.................................. $2.50

FISHER, H. K. C. and DARBY, W. C. Students' Guide to Submarine Cable Testing. 8vo, cloth................$2.50

FISHER, W. C. The Potentiometer and its Adjuncts. 8vo, cloth...$2.25

FLEISCHMANN, W. The Book of the Dairy. A Manual of the Science and Practice of Dairy Work. Translated from the German, by C. M. Aikman and R. Patrick Wright. 8vo, cloth...$4.00

FLEMING, Prof. J. A. The Alternate Current Transformer in Theory and Practice. Vol. I—The Induction of Electric Currents; 611 pages. New edition. Illustrated. 8vo, cloth...$5.00
Vol. 2. The Utilization of Induced Currents. Illustrated. 8vo, cloth..$5.00

—— Centenary of the Electrical Current, 1799-1899. 8vo, paper, illustrated.. .50

—— Electric Lamps and Electric Lighting. Being a course of four lectures delivered at the Royal Institution, April-May, 1894. 8vo, cloth, fully illustrated...... ....$3.00

—— Electrical Laboratory Notes and Forms, Elementary and advanced. 4to, cloth, illustrated....................$5.00

—— A Handbook for the Electrical Laboratory and Testing Room. Vol. I. 8vo, cloth...........................$5.00

FOLEY, NELSON and THOS. PRAY, Jr. The Mechanical Engineers' Reference Book for Machine and Boiler Construction, in two parts. Part 1—General Engineering Data. Part 2—Boiler Construction. With fifty-one plates and numerous illustrations, specially drawn for this work. Folio, half morocco......$25.00

FORNEY, MATTHIAS N. Catechism of the Locomotive. *Second Edition, revised and enlarged* Forty-sixth thousand. 8vo, cloth $3.50

FOSTER, Gen. J. G., U.S.A. Submarine Blasting in Boston Harbor, Massachusetts. Removal of Tower and Corwin Rocks. Illustrated with 7 plates. 4to, cloth $3.50

FOSTER, H. A. Electrical Engineers' Pocket Book. With the Collaboration of Eminent Specialists. A handbook of useful data for Electricians and Electrical Engineers. With innumerable tables, diagrams and figures. *Second edition, revised.* Pocket size, full leather, 1000 pages...$5.00

FOSTER, JAMES. Treatise on the Evaporation of Saccharine, Chemical and other Liquids by the Multiple System in Vacuum and Open Air. *Second Edition.* Diagrams and large plates. 8vo, cloth $7.50

FOX, WM., and C. W. THOMAS, M. E. A Practical Course in Mechanical Drawing. *Second edition, revised.* 12mo, cloth with plates.............. ....$1.25

FRANCIS, Jas. B., C.E. Lowell Hydraulic Experiments. Being a selection from experiments on Hydraulic Motors, on the Flow of Water over Weirs, in open Canals of uniform rectangular section, and through submerged Orifices and diverging Tubes. Made at Lowell, Mass. *Fourth edition, revised and enlarged,* with many new experiments, and illustrated with 23 copper-plate engravings. 4to, cloth........................$15.00

FROST, GEO. H. Engineer's Field Book. By C. S. Cross. To which are added seven chapters on Railroad Location and Construction. *Fourth edition.* 12mo, cloth..................$1.00

FULLER, GEORGE W. Report on the Investigations into the Purification of the Ohio River Water at Louisville, Kentucky, made to the President and Directors of the Louisville Water Company. Published under agreement with the Directors. 3 full page plates. 4to, cloth................................*net,* $10.00

GARCKE, EMILE, and J. M. FELLS. Factory Accounts; their principles and practice. A handbook for accountants and manufacturers, with appendices on the nomenclature of machine details, the rating of factories, fire and boiler insurance, the factory and workshop acts, etc., including also a large number of specimen rulings. *Entirely new and revised edition.* 8vo, cloth, illus..*In Press.*

GEIPEL, WM. and KILGOUR, M. H. A Pocketbook of Electrical Engineering Formulæ. Illustrated. 18mo, mor..$3.00

GERBER, NICHOLAS. Chemical and Physical Analysis of Milk, Condensed Milk and Infant's Milk-Food. 8vo, cloth...$1.25

GERHARD, WM. P. Sanitary Engineering. 12mo, cloth $1.25

GESCHWIND, LUCIEN. Manufacture of Alum and Sulphates, and other Salts of Alumnia and Iron; their uses and applications as mordants in dyeing and calico printing, and their other applications in the Arts, Manufactures, Sanitary Engineering, Agriculture and Horticulture. Translated from the French by Charles Salter. With tables, figures and diagrams. 8vo, cloth, illus...*net.* $5.00

GIBBS, WILLIAM E. Lighting by Acetylene, Generators, Burners and Electric Furnaces. With 66 illustrations. *Second edition revised.* 12mo, cloth............................$1.50

GILLMORE, Gen. Q. A. Treatise on Limes, Hyraulic Cements, and Mortars. Papers on Practical Engineering, United States Engineer Department, No. 9, containing Reports of numerous Experiments conducted in New York City during the years 1858 to 1861, inclusive. With numerous illustrations. 8vo, cloth......$4.00

GILLMORE, Gen. Q. A. Practical Treatise on the Construction of Roads, Streets, and Pavements. *Tenth Edition.* With 70 illustrations. 12mo, cloth...............................$2.00

—— **Report on Strength of the Building Stones in the** United States, etc. 8vo, illustrated, cloth......................$1.00

GOLDING, HENRY A. The Theta-Phi Diagram. Practically applied to Steam, Gas, Oil and Air Engines. 12mo, cloth. Illustrated...*net,* $1.25

GOODEVE, T. M. A Text-Book on the Steam-Engine. With a Supplement on Gas-Engines. *Twelfth Edition, enlarged.* 143 illustrations. 12mo, cloth..............................$2.00

GORE, G., F. R. S. The Art of Electrolytic Separation of Metals, etc. (Theoretical and Practical.) Illustrated. 8vo, cloth...$3.50

GOULD, E. SHERMAN. The Arithmetic of the Steam Engine. 8vo, cloth....................................$1.00

GRIFFITHS, A. B., Ph.D. A Treatise on Manures, or the Philosophy of Manuring. A Practical Hand-Book for the Agriculturist, Manufacturer, and Student. 12mo, cloth........$3.00

GROSS, EMANUEL. Hops, in their Botanical, Agricultural and Technical Aspect, and as an article of Commerce. Translated from the German by Charles Salter. With tables, diagrams and illustrations. 8vo, cloth, illustrated.....................*net.* $4.50

GROVER, FREDERICK. Practical Treatise on Modern Gas and Oil Engines. 8vo, cloth. Illustrated........... $2.00

GRUNER, ANTON. Power-loom Weaving and Yarn Numbering, according to various systems, with conversion tables. An auxiliary and text-book for pupils of weaving schools, as well as for self-instruction, and for general use by those engaged in the weaving industry. Illustrated with colored diagrams. 8vo, cloth...*net.* $3.00

GURDEN, RICHARD LLOYD. Traverse Tables: computed to 4 places Decimals for every ° of angle up to 100 of Distance. For the use of Surveyors and Engineers. *New Edition.* Folio, half morocco..$7.50

GUY, ARTHUR F. Electric Light and Power, giving the Result of Practical Experience in Central-Station Work. 8vo, cloth. Illustrated..$2.50

HAEDER, HERMAN, C. E. A Handbook on the Steam Engine. With especial reference to small and medium sized engines. English edition, re-edited by the author from the second German edition, and translated with considerable additions and alterations by H. H. P. Powles. 12mo, cloth. Nearly 1100 illus. ..$3.00

HALL, WM. S. Prof. Elements of the Differential and Integral Calculus. *Fourth edition, revised.* 8vo, cloth Illustrated..*net,* $2.25

—— **Descriptive Geometry, with numerous Problems** and Practical applications. Two vols. (Plates and Text)...*In Press.*

HALSEY, F. A. Slide Valve Gears, an Explanation of the action and Construction of Plain and Cut-off Slide Valves. Illustrated. 12mo, cloth. *Seventh Edition*....................$1.50

—— **The Use of the Slide Rule. With illustrations and** folding plates. *Second edition.* 16mo, boards. (*Van Nostrand's Science Series,* No. 114.)....................................$0.50

—— **The Locomotive Link Motion, with Diagrams and** Tables. 8vo. cloth, illustrated....................................$1.00

—— **Worm and Spiral Gearing.** 16mo, cloth, (Van Nostrand's Science Series, No. 116). Illustrated....................$0.50

HAMILTON, W. G. Useful Information for Railway Men. *Tenth Edition, revised and enlarged.* 562 pages, pocket form. Morocco, gilt....................................$2.00

HANCOCK, HERBERT. Text-Book of Mechanics and Hydrostatics, with over 500 diagrams. 8vo, cloth..............$1.75

HARRISON, W. B. The Mechanics' Tool Book. With Practical Rules and Suggestions for use of Machinists, Iron-Workers, and others. Illustrated with 44 engravings. 12mo, cloth,..$1.50

HART, JOHN W. External Plumbing Work; a Treatise on Lead Work for Roofs. With numerous figures and diagrams. 8vo, cloth, illustrated....................................$3.00

—— **Hints to Plumbers on Joint Wiping, Pipe Bending** and Lead Burning. Containing 184 figures and diagrams. 8vo, cloth, illustrated..$3.00

—— **Principles of Hot Water Supply. With numerous** illustrations. 8vo, cloth..................................*net,* $3.00

HASKINS, C. H. The Galvanometer and its Uses. A Manual for Electricians and Students. Fourth edition. 12mo, cloth...$1.50

HAUFF, W. A. American Multiplier; Multiplications and Divisions of the largest numbers rapidly performed. With index giving the results instantly of all numbers to 1000 x 1000 = 1,000,000; also tables of circumferences and areas of circles. Cloth, 6½ x 15½. $5.00

HAUSNER, A. Manufacture of Preserved Foods and Sweetmeats. A Handbook of all the Processes for the Preservation of Flesh, Fruit, and Vegetables, and for the Preparation of Dried Fruit, Dried Vegetables, Marmalades, Fruit-Syrups, and Fermented Beverages, and of all kinds of Candies, Candied Fruit, Sweetmeats, Rocks, Drops, Dragees, Pralines, etc. Translated from the Third Enlarged German Edition, by Arthur Morris and Herbert Robson, B. Sc. 8vo, cloth, illustrated, 223 pages...........................*net,* $3.00

HAUSBRAND, E. Drying by Means of Air and Steam. With explanations, formulas and tables, for use in practice. Translated from the German by A. C. Wright, M. A. 12mo, cloth, illustrated $2.00

HAWKE, WILLIAM H. The Premier Cipher Telegraphic Code Containing 100,000 Words and Phrases. The most complete and most useful general code yet published. 4to, cloth . $5.00

—— 100,000 Words Supplement to the Premier Code. All the words are selected from the official vocabulary. Oblong quarto, cloth $4.20

HAWKINS, C. C., and WALLIS, F. The Dynamo; its Theory, Design and Manufacture. 190 illustrations, 12mo, cloth, ... $3.00

HAY, ALFRED. Principles of Alternate-Current Working. 12mo, cloth, illustrated........................ $2.00

HEAP, Major D. P., U. S. A. Electrical Appliances of the Present Day. Report of the Paris Electrical Exposition of 1881. 250 illustrations. 8vo, cloth $2.00

HEAVISIDE, OLIVER. Electromagnetic Theory. 8vo, cloth, two volumes........................ each, $5.00

HEERMANN, PAUL. Dyers' Materials: an introduction to the Examination, Valuation and Application of the most important substances used in Dyeing, Printing, Bleaching and Finishing. Translated by Arthur C. Wright, M. A. 12mo, cloth, illustrated .... *net,* $2.50

HENRICI, OLAUS. Skeleton Structures, Applied to the Building of Steel and Iron Bridges. 8vo, cl., Illustrated.. $1.50

HERRMANN, Gustav. The Graphical Statics of Mechanism. A Guide for the Use of Machinists, Architects, and Engineers; and also a Text-book for Technical Schools. Translated and annotated by A. P. Smith, M. E. 12mo, cloth, 7 folding plates. *Fourth Edition* $2.00

HERMANN, FELIX. Painting on Glass and Porcelain and Enamel Painting. On the Basis of Personal Practical Experience of the Condition of the Art up to date. Translated by Charles Salter. *Second greatly enlarged edition.* 8vo, cloth. Illustrated........................ *net,* $3.50

HERZFELD, DR. J. The Technical Testing of Yarns and Textile Fabrics, with reference to official specifications. Translated by Chas. Salter. With 69 illustrations. 8vo, cloth .. *net,* $3.50

HEWSON, WM. Principles and Practice of Embanking Lands from River Floods, as applied to the Levees of the Mississippi. 8vo, cloth $2.00

HILL, JOHN W. The Purification of Public Water Supplies. Illustrated with valuable Tables, Diagrams and Cuts. 8vo, cloth, 304 pages $3.00

HOBBS, W. R. P. The Arithmetic of Electrical Measurements, with numerous examples, fully worked. Revised by Richard Wormell, M. A. *Ninth edition.* 12mo, cloth......... $0.50

HOFF, WM. B., Com. U. S. Navy. The Avoidance of Collisions at Sea. 18mo, morocco .... .75

HOLLEY, ALEXANDER L. Railway Practice. American and European Railway practice in the Economical Generation of Steam, including the Materials and Construction of Coal-burning Boilers, Combustion, the Variable Blast, Vaporization, Circulation, Superheating, Supplying and Heating Feed Water, etc., and the Adaptation of Wood and Coke-burning Engines to Coal-burning; and in Permanent Way, including Road-bed, Sleepers, Rails, Joint Fastenings, Street Railways, etc. With 77 lithographed plates. Folio, cloth... $12.00

HOLMES, A. BROMLEY. The Electric Light Popularly Explained. *Fifth Edition.* Illustrated. 12mo, paper... $0.40

HOPKINS, NEVIL M. Model Engines and Small Boats. New Methods of Engine and Boiler Making with a chapter on Elementary Ship Design and Construction. 12mo, cloth........ $1.25

HOSPITALIER, E. Polyphased Alternating Currents. Illustrated. 8vo, cloth.................................... $1.40

HOWARD, C. R. Earthwork Mensuration on the Basis of the Prismoidal Formulæ. Containing Simple and Labor-saving Method of obtaining Prismoidal Contents directly from End Areas. Illustrated by Examples and accompanied by Plain Rules for Practical Uses. Illustrated. 8vo, cloth...... .... $1.50

HOWORTH, J. Art of Repairing and Riveting Glass, China and Earthenware. *Second edition.* 8vo, pamphlet, illustrated.. *net,* $0.50

HUMBER, WILLIAM, C. E. A Handy Book for the Calculation of Strains in Girders, and Similar Structures, and their Strength; Consisting of Formulæ and Corresponding Diagrams, with numerous details for practical application, etc. *Fourth Edition.* 12mo, cloth........... ....$2.50

HURST, GEO. H., F. C. S. **Color; a Hand-book of** the Theory of Color. A practical work for the Artist, Art Student, Painter, Dyer and Calico Printer and Others. Illustrated with 10 colored plates and 72 illustrations. 8vo, cloth............... ..$2.50

—— **Dictionary of Chemicals and Raw Products used** in the Manufacture of Paints, Colors, Varnishes and Allied Preparations. 8vo, cloth.......................... ....*net,* $3.00

HURST, GEO. H., F. C. S. **Lubricating Oils, Fats and** Greases; Their Origin, Preparation, Properties, Uses and Analysis. 313 pages, with 65 illustrations. 8vo, cloth..............*net,* $3.00

—— **Soaps; A Practical Manual of the Manufacture of** Domestic, Toilet and other Soaps. Illustrated with 66 Engravings. 8vo, cloth..*net,* $5.00

HUTCHINSON, W. B. *Member of the New York Bar.* Patents and How to Make Money out of Them. 12mo, cloth...$1.25

HUTTON, W. S. Steam Boiler Construction. A Practical Hand Book for Engineers, Boiler Makers and Steam Users. Containing a large collection of rules and data relating to recent practice in the design, construction, and working of all kinds of stationary, locomotive and marine steam-boilers. With upwards of 500 illustrations. *Third Edition, carefully revised and much enlarged.* 8vo, cloth..$6.00

—— **Practical Engineer's Hand-Book, Comprising a** treatise on Modern Engines and Boilers, Marine, Locomotive and Stationary. *Fourth Edition. Carefully revised with additions.* With upwards of 570 illustrations. 8vo, cloth................$7.00

—— **The Works' Manager's Hand-Book of Modern** Rules, Tables, and Data for Civil and Mechanical Engineers. Millwrights and Boiler-makers, etc., etc. With upwards of 150 illustrations. *Fifth Edition. Carefully revised, with additions.* 8vo, cloth..$6.00

INNES, CHARLES H. Problems in Machine Design, For the Use of Students, Draughtsmen and others. *Second edition.* 12mo, cloth...*net,* $2.00

—— **Centrifugal Pumps, Turbines, and Water Motors.** Including the Theory and Practice of Hydraulics. *Third and enlarged edition.* 12mo, cloth......................... *net,* $2.00

ISHERWOOD, B. F. Engineering Precedents for Steam Machinery. Arranged in the most practical and useful manner for Engineers. With illustrations. 2 vols. in 1. 8vo, cloth......$2.50

JAMESON, CHARLES D. Portland Cement. Its Manufacture and Use. 8vo, cloth $1.50

JAMIESON, ANDREW, C.E. A Text-Book on Steam and Steam-Engines. Specially arranged for the use of Science and Art, City and Guilds of London Institute, and other Engineering Students. *Thirteenth Edition.* Illustrated. 12mo, cloth.....$3.00

—— **Elementary Manual on Steam and the Steam Engine.** Specially arranged for the use of First-Year Science and Art, City and Guilds of London Institute, and other Elementary Engineering Students. *Third Edition.* 12mo, cloth....................$1.50

JANNETTAZ, EDWARD. A Guide to the Determination of Rocks: being an Introduction to Lithology. Translated from the French by G. W. Plympton, Professor of Physical Science at Brooklyn Polytechnic Institute. 12mo, cloth...... ....$1.50

JEHL, FRANCIS. Member A. I. E. E. The manufacture of Carbons for Electric Lighting and Other Purposes. A Practical Hand-book, giving a complete description of the art of making carbons, electros, etc. The various gas generators and furnaces used in carbonising, with a plan for a model factory. Illustrated with numerous diagrams, tables and folding plates. 8vo, cloth, illustrated...$4.00

JENNISON, FRANCIS H. The Manufacture of Lake Pigments from Artificial Colors. A useful handbook for color manufacturers, dyers, color chemists, paint manufacturers, drysalters, wall-paper makers, enamel and surface-paper makers. With fifteen plates illustrating the various methods and errors that arise in the different processes of production. 8vo, cloth, illustrated ..*net*, $3.00

JOHNSTON, Prof. J. F. W., and CAMERON, Sir Chas. Elements of Agricultural Chemistry and Geology. *Seventeenth Edition.* 12mo, cloth.......................................$2.60

JONES, HARRY C. Outlines of Electrochemistry. With tables and diagrams. 4to, cloth, illustrated..............$1.50

JONES, M. W. The Testing and Valuation of Raw Materials used in Paint and Color Manufacture. 12mo, cl...*net.* $2.00

JOYNSON, F. H. The Metals used in Construction. Iron, Steel, Bessemer Metal, etc. Illustrated. 12mo, cloth.... .75

—— Designing and Construction of Machine Gearing. Illustrated. 8vo, cloth $2.00

KANSAS CITY BRIDGE, THE With an Account of the Regimen of the Missouri River and a Description of the Methods used for Founding in that River. By O. Chanute, Chief Engineer, and George Morrison, Assistant Engineer. Illustrated with 5 lithographic views and 12 plates of plans. 4to, cloth.......................$6.00

KAPP, GISBERT, C.E. Electric Transmission of Energy and its Transformation, Subdivision, and Distribution. A Practical hand-book. *Fourth Edition, revised* 12mo, cloth.. ....$3.50

—— Dynamos, Motors, Alternators and Rotary Converters. Translated from the Third German Edition, by Harold H. Simmons, A. M. I. E. E., with numerous diagrams and figures. 8vo, cloth, 507 pages...$4.00

KEMP, JAMES FURMAN, *A. B., E. M.* A Hand-Book of Rocks; for use without the microscope. With a glossary of the names of rocks and of other lithological terms. 8vo, cloth, illustrated...$1.50

KEMPE, H. R. The Electrical Engineer's Pocket Book of Modern Rules, Formulæ, Tables and Data. Illustrated. 32mo. Morocco, gilt...................................$1.75

KENNELLY, A. E. Theoretical Elements of Electro-Dynamic Machinery. 8vo, cloth $1.50

KILGOUR, M. H., SWAN, H., and BIGGS, C. H. W. Electrical Distribution; Its Theory and Practice. 174 Illustrations. 12mo, cloth $4.00

KING, W. H. Lessons and Practical Notes on Steam. The Steam-Engine, Propellers, etc., for Young Marine Engineers, Students, and others. Revised by Chief Engineer J. W. King, United States Navy. *Nineteenth Edition, enlarged.* 8vo, cloth....... $2.00

KINGDON, J. A. Applied Magnetism. An introduc-tion to the Design of Electromagnetic Apparatus. 8vo, cloth... $3.00

KIRKALDY, Wm. G. Illustrations of David Kirk-aldy's System of Mechanical Testing, as Originated and Carried On by him during a Quarter of a Century. Comprising a Large Selection of Tabulated Results, showing the Strength and other Properties of Materials used in Construction, with Explanatory Text and Historical Sketch. Numerous engravings and 25 lithographed plates. 4to, cloth $20.00

KIRKWOOD, JAS. P. Report on the Filtration of River Waters for the supply of Cities, as practised in Europe, made to the Board of Water Commissioners of the city of St. Louis. Illustrated by 30 double-plate engravings. 4to, cloth.............. $7.50

KNIGHT, AUSTIN M., (*Lieutenant-Commander U. S. N.*) Modern Seamanship. Illustrated with 136 full page plates and diagrams. 8vo, cloth, illustrated. *Second edition, revised... net* $6.00
Half morocco $7.50

KOLLER, THEODOR. The Utilization of Waste Products. A Treatise on the Rational Utilization, Recovery and Treatment of Waste Products of all kinds. Translated from the German Second Revised Edition. With numerous diagrams. 8vo, cloth, illustrated, 280 pages .... *net,* $3.50

LAMBERT, THOMAS Bone Products and Manures: an account of the most recent improvements in the manufacture of Fat, Glue, Animal Charcoal, Size, Gelatine and Manures. With plans and diagrams. 8vo, cloth, Illustrated .... *net* $3.00

LAMPRECHT, ROBERT. Recovery Work after Pit Fires; a description of the principal methods pursued, especially in fiery mines, and of the various appliances employed, such as respiratory and rescue apparatus, dams, etc. With folding plates and diagrams. Translated from the German by Charles Salter. 8vo, cloth, illustrated .... *net,* $4.00

LARRABEE, C. S. Cipher and Secret Letter and Tele-graphic Code, with Hog's Improvements. The most perfect Secret Code ever invented or discovered. Impossible to read without the key. 18mo, cloth .... .60

LASSAR-COHN, Dr. An Introduction to Modern Scientific Chemistry, in the form of popular lectures suited to University Extension Students and general readers. Translated from the author's corrected proofs for the second German edition. By M. M. Pattison Muir, M. A. 12mo, cloth, illustrated................$2.00

LEASK, A. RITCHIE. Breakdowns at Sea and How to Repair Them. With eigthy-nine illustrations. *Second Edition.* 8vo, cloth.... ....$2.00

—— **Triple and Quadruple Expansion Engines and** Boilers and their Management. With fifty-nine illustrations. *Third edition, revised.* 12mo, cloth...............................$2.00

—— **Refrigerating Machinery: Its Principles and Man**agement. With sixty-four illustrations. 12mo, cloth..........$2.00

LECKY, S. T. S. "Wrinkles" in Practical Navigation. With 130 illustrations. 8vo, cloth *Ninth Edition, revised*....$8.40

LEFÊVRE, LEON. Architectural Pottery: Bricks, Tiles, Pipes, Enameled Terra-Cottas, Ordinary and Incrusted Quarries, Stoneware Mosaics, Faiences, and Architectural Stoneware. With tables, plates and 950 cuts and illustrations. With a preface by M. J.-C. Formigé. Translated from the French by K. H. Bird, M. A. and W. Moore Binns. 4to, cloth, illustrated.............. *net* $7.50

LEHNER, SIGMUND. Ink Manufacture: including Writing, Copying, Lithographic, Marking, Stamping] and Laundry Inks. Translated from the Fifth German Edition by Arthur Morris and Herbert Robson, B. Sc. 8vo, cloth, illustrated, 162 pages. ....*net*, $2.50

LEVY, C. L. Electric Light Primer. A Simple and Comprehensive digest of all the most important facts connected with the running of the dynamo, and electric lights, with precautions for safety. For the use of persons whose duty it is to look after the plant. 8vo, paper...... ....$ .50

LIVACHE, ACH.—(*Ingenieur Civil Des Mines.*) **The Man**ufacture of Varnishes, Oil Crushing, Refining and Boiling and Kindred Industries. Describing the Manufacture and Chemical and Physical Properties of Spirit Varnishes and Oil Varnishes ; Raw Materials; Resins; Solvents and Coloring Principles; Drying Oils; their Extraction, Properties and Applications, Oil Refining and Boiling ; The Manufacture; Employment and Testing of Various Varnishes Translated from the French, by John Geddes McIntosh. Greatly extended and adapted to English practice. With numerous original recipes, by the translator. Illustrated with cuts and diagrams. 8vo, cloth, illustrated...........................*net.* $5.00

LOBBEN, PEDER, M. E. Machinists' and Draftsmen's Hand-Book, containing Tables, Rules and Formulas, with numerous examples, explaining the principles of mathematics and mechanics, as applied to the mechanical trades. Intended as a reference book for all interested in Mechanical work. Illustrated with many cuts and diagrams. 8vo, cloth $2.50

LOCKE, ALFRED G. and CHARLES G. A Practical Treatise on the Manufacture of Sulphuric Acid. With 77 Constructive Plates drawn to Scale Measurements, and other Illustrations. Royal 8vo, cloth $10.00

LOCKERT, LOUIS. Petroleum Motor-Cars. 12mo, cloth..$1.50

LOCKWOOD, THOS. D. Electricity, Magnetism, and Electro-Telegraphy. A Practical Guide for Students, Operators, and Inspectors. 8vo, cloth. *Third Edition*........................$2.50

—— Electrical Measurement and the Galvanometer; Its Construction and Uses. *Second Edition.* 32 illustrations. 12mo, cloth..$1.50

LODGE, OLIVER J. Elementary Mechanics, including Hydrostatics and Pneumatics. *Revised Edition.* 12mo, cloth..$1.50

LODGE, OLIVER J. Signalling Across Space, Without Wires; being a description of the work of Hertz and his successors. With numerous diagrams and half tone cuts, and additional remarks concerning the application to Telegraphy and later developments. *Third edition.* 8vo, cloth, illustrated....................*net,* $2.00

LORD, R. T. Decorative and Fancy Fabrics. A valuable Book with designs and illustrations for manufacturers and designers of Carpets, Damask, Dress and all Textile Fabrics. 8vo, cloth, illustrated..*net,* $3.50

LORING, A. E. A Hand-Book of the Electro-Magnetic Telegraph. Cloth, boards. *New and enlarged edition*........ .50

LUCE, Com. S. B. Text-Book of Seamanship. The Equipping and Handling of Vessels under Sail or Steam. For the use of the U. S. Naval Academy. *Revised and enlarged edition,* by Lt. Wm. S. Benson. 8vo, cloth........................ $10.00

LUNGE, GEORGE. Ph. D. **Coal-Tar and Ammonia;** being the third and enlarged edition of "A Treatise on the Distillation of Coal-tar and Ammoniacal Liquor," with numerous tables, figures and diagrams. Thick 8vo, cloth, illustrated......... *net* $15.00

—— A Theoretical and Practical Treatise on the Manufacture of Sulphuric Acid and Alkali with the Collateral Branches.
Vol. I. Sulphuric Acid. *Second Edition, Revised and enlarged.* 342 illustrations. 8vo, cloth........................$15.00
Vol. II. *Second Edition, revised and enlarged.* 8vo, cloth..$16.80
Vol. III. 8vo, cloth. *New Edition,* 1896...................$15.00

LUNGE, GEO., and HURTER, F. The Alkali Maker's Pocket Book. Tables and Analytical Methods for Manufacturers of Sulphuric Acid, Nitric Acid, Soda, Potash and Ammonia. *Second Edition.* 12mo, cloth..$3.00

LUQUER, LEA McILVAINE, Ph. D. Minerals in Rock Sections. The Practical Method of Identifying Minerals in Rock Sections with the Microscope. Especially arranged for Students in Technical and Sientific Schools. 8vo, cloth. Illustrated........................ ....*net,* $1.50

MACCORD, Prof. C. W. A Practical Treatise on the Slide-Valve by Eccentrics, examining by methods the action of the Eccentric upon the Slide-Valve, and explaining the practical processes of laying out the movements, adapting the Valve for its various duties in the Steam-Engine. *Second Edition.* Illustrated. 4to, cloth..$2.50

MACKROW, CLEMENT. The Naval Architect's and Ship-Builder's Pocket-Book of Formulæ, Rules and Tables; and Engineers' and Surveyors' Handy-Book of Reference. *Seventh edition.* 16mo, limp leather, illustrated.................... ....$5.00

MAGUIRE, Capt. EDWARD, U. S. A. The Attack and Defence of Coast Fortifications. With Maps and Numerous Illustrations. 8vo, cloth......................................$2.50

MAGUIRE, WM. R. Domestic Sanitary Drainage and Plumbing Lectures on Practical Sanitation. 332 illustrations. 8vo $4.00

MARKS, EDWARD C. R. Mechanical Engineering Materials: Their Properties and Treatment in Construction. 12mo, cloth. Illustrated... .60

—— Notes on the Construction of Cranes and Lifting Machinery. With numerous diagrams and figures. *New and enlarged edition.* 12mo, cloth.............................*net,* $1.50

MARKS, G. C. Hydraulic Power Engineering: a Practical Manual on the Concentration and Transmission of Power by Hydraulic Machinery. With over two hundred diagrams and tables. 8vo, cloth, illustrated $3.50

MAVER, WM. American Telegraphy: Systems, Apparatus, Operation. 450 illustrations. 8vo, cloth..... ....$3.50

MAYER, Prof. A. M. Lecture Notes on Physics. 8vo, cloth..$2.00

McCULLOCH, Prof. R. S. Elementary Treatise on the Mechanical Theory of Heat, and its application to Air and Steam Engines. 8vo, cloth...$3.50

McNEILL, BEDFORD. McNeill's Code. Arranged to meet the requirements of Mining, Metallurgical and Civil Engineers, Directors of Mining, Smelting and other Companies, Bankers, Stock and Share Brokers, Solicitors, Accountants, Financiers, and General Merchants. Safety and Secrecy. 8vo, cloth $6.00

McPHERSON, J. A. (*A. M Inst. C. E.*) **Waterworks** Distribution; a practical guide to the laying out of systems of distributing mains for the supply of water to cities and towns. With tables, folding plates and numerous full-page diagrams. 8vo, cloth, ill. $2.50

MERRITT, WM. HAMILTON. Field Testing for Gold and Silver. A Practical Manual for Prospectors and Miners. With numerous half-tone cuts, figures and tables. 16mo, limp leather, Illustrated.......................................$1.50

METAL TURNING. By a Foreman Pattern Maker. Illustrated with 81 engravings. 12mo, cloth..................$1.50

MICHELL, STEPHEN. Mine Drainage; being a complete Practical Treatise on Direct-Acting Underground Steam Pumping Machinery. Containing many folding plates, diagrams and tables. *Second edition, re-written and enlarged.* Thick, 8vo, cloth, illus. $10.00

MINIFIE, WM. Mechanical Drawing. A Textbook of Geometrical Drawing for the use of Mechanics and Schools, in which the Definitions and Rules of Geometry are familiarly explained; the Practical Problems are arranged from the most simple to the more complex, and in their description technicalities are avoided as much as possible. With illustrations for Drawing Plans, Sections, and Elevations of Railways and Machinery; an Introduction to Isometrical Drawing, and an Essay on Linear Perspective and Shadows. Illustrated with over 200 diagrams engraved on steel. Ninth thousand. With an appendix on the Theory and Application of Colors. 8vo, cloth..$4.00

—— Geometrical Drawing. Abridged from the Octavo edition, for the use of schools. Illustrated with 48 steel plates. *Ninth edition.* 12mo, cloth.................................$2.00

MODERN METEOROLOGY. A Series of Six Lectures, delivered under the auspices of the Meteorological Society in 1870. Illustrated. 12mo, cloth...................................$1.50

MOORE, E. C. S. New Tables for the Complete Solution of Ganguillet and Kutter's Formula for the flow of liquids in open channels, pipes, sewers and conduits. In two parts. Part I, arranged for 1,080 inclinations from 1 over 1, to 1 over 21,120 for fifteen different values of (*n*). Part II, for use with all other values of (*n*). With large folding diagram. 8vo, cloth, illustrated. .*net,* $5.00

MOREING, C. A., and NEAL, THOMAS. New General and Mining Telegraph Code. 676 pages alphabetically arranged. For the use of mining companies, mining engineers, stockbrokers, financial agents, and trust and finance companies. 8vo, cloth..:$8.40

MOSES, ALFRED J., and PARSONS, C. L. Elements of Mineralogy, Crystallography and Blowpipe Analysis from a practical standpoint. *Second Thousand.* 8vo, cloth, 336 illus..*net,* $2.00

MOSES, ALFRED J. The Characters of Crystals. An Introduction to Physical Crystallography, containing 321 Illustrations and Diagrams. 8vo, 211 pp.........................*net,* $2.00

MULLIN, JOSEPH P., M.E. Modern Moulding and Pattern-Making. A Practical Treatise upon Pattern-Shop and Foundry Work: embracing the Moulding of Pulleys, Spur Gears, Worm Gears, Balance-Wheels, Stationary Engine and Locomotive Cylinders, Globe Valves, Tool Work, Mining Machinery, Screw Propellers, Pattern-Shop Machinery, and the latest improvements in English and American Cupolas; together with a large collection of original and carefully selected Rules and Tables for every-day use in the Drawing Office, Pattern-Shop and Foundry. 12mo, cloth, illustrated....$2.50

MUNRO, JOHN, C.E., and JAMIESON, ANDREW, C. E. A Pocketbook of Electrical Rules and Tables for the use of Electricians and Engineers. *Fifteenth edition, revised and enlarged.* With numerous diagrams. Pocket size. Leather.$2.50

MURPHY, J. G., M.E. Practical Mining. A Field Manual for Mining Engineers. With Hints for Investors in Mining Properties. 16mo, morocco tucks...........................$1.00

NAQUET, A. Legal Chemistry. A Guide to the Detection of Poisons, Falsification of Writings, Adulteration of Alimentary and Pharmaceutical Substances, Analysis of Ashes, and examination of Hair, Coins, Arms, and Stains, as applied to Chemical Jurisprudence, for the use of Chemists, Physicians, Lawyers, Pharmacists and Experts. Translated, with additions, including a list of books and memoirs on Toxicology, etc., from the French, by J. P. Battershall, Ph.D., with a preface by C. F. Chandler, Ph.D., M.D., LL.D. 12mo, cloth..$2.00

NASMITH, JOSEPH, The Student's Cotton Spinning. *Third edition, revised and enlarged.* 8vo, cloth, 622 pages, 250 illustrations...$3.00

NEUBURGER, HENRY and HENRI NOALHAT. Technology of Petroleum. The Oil Fields of the World; their History, Geography and Geology. Annual Production, Prospection and Development. Oil-well Drilling, Transportation of Petroleum by land and sea. Storage of Petroleum. With 153 illustrations and 25 plates. Translated from the French by John Geddes McIntosh. 8vo, cloth, illustrated...................................*net,* $10.00

NEWALL, JOHN W. Plain Practical Directions for Drawing, Sizing and Cutting Bevel-Gears, showing how the Teeth may be cut in a Plain Milling Machine or Gear Cutter so as to give them a correct shape from end to end; and showing how to get out all particulars for the Workshop without making any Drawings. Including a Full Set of Tables of Reference. Folding Plates. 8vo, cloth...$1.50

NEWLANDS, JAMES. **The Carpenters' and Joiners' Assistant**: being a Comprehensive Treatise on the Selection, Preparation and Strength of Materials, and the Mechanical Principles of Framing, with their application in Carpentry, Joinery, and Hand-Railing; also, a Complete Treatise on Sines; and an illustrated Glossary of Terms used in Architecture and Building. Illustrated. Folio, half morocco...$15.00

NIPHER, FRANCIS E., A.M. **Theory of Magnetic** Measurements, with an appendix on the Method of Least Squares. 12mo, cloth...$1.00

NUGENT, E. **Treatise on Optics; or, Light and Sight** theoretically and practically treated, with the application to Fine Art and Industrial Pursuits. With 103 illustrations. 12mo, cloth...$1.50

O'CONNOR, HENRY. **The Gas Engineer's Pocket** Book. Comprising Tables, Notes and Memoranda; relating to the Manufacture, Distribution and Use of Coal Gas and the Construction of Gas Works. *Second edition, revised.* 12mo, full leather, gilt edges...$3.50

OSBORN, FRANK C. **Tables of Moments of Inertia,** and Squares of Radii of Gyration; Supplemented by others on the Ultimate and Safe Strength of Wrought Iron Columns, Safe Strength of Timber Beams, and Constants for readily obtaining the Shearing Stresses, Reactions, and Bending Moments in Swing Bridges. 12mo, leather...$3.00

OSTERBERG, MAX. **Synopsis of Current Electrical** Literature, compiled from Technical Journals and Magazines during 1895. 8vo, cloth...$1.00

OUDIN, Maurice A. **Standard Polyphase Apparatus** and Systems. With many diagrams and figures. *Third edition, thoroughly revised.* Fully Illustrated. $3.00

PAGE, DAVID. **The Earth's Crust, A Handy Outline** of Geology. 16mo, cloth.................................. .75

PALAZ, A., ScD. **A Treatise on Industrial Photometry**, with special application to Electric Lighting. Authorized translation from the French by George W. Patterson, Jr. *Second edition, revised.* 8vo, cloth. Illustrated...........................$4.00

PARRY, ERNEST J., B. Sc. **The Chemistry of Essential Oils and Artificial Perfumes.** Being an attempt to group together the more important of the published facts connected with the subject; also giving an outline of the principles involved in the preparation and analysis of Essential Oils. With numerous diagrams and tables. 8vo, cloth, illustrated ....*net.* $5.00

PARRY, LEONARD A., M. D. The Risks and Dangers of Various Occupations and their Prevention. A book that should be in the hands of manufacturers, the medical profession, sanitary inspectors, medical officers of health, managers of works, foremen and workmen. 8vo, cloth. ....*net.* $3.00

PARSHALL, H. F., and HOBART, H. M. Armature Windings of Electric Machines. With 140 full page plates, 65 tables, and 165 pages of descriptive letter-press. 4to, cloth......$7.50

PARSHALL, H. F., and EVAN PARRY. Electrical Equipment of Tramways.............................(*In Press.*)

PATERSON, DAVID, F. C. S. The Color Printing of Carpet Yarns ; a useful manual for color chemists and textile printers. With numerous illustrations. 8vo, cloth, illustrated..........*net.* $3.50

—— Colour Matching on Textiles; a Manual intended for the use of Dyers, Calico Printers and Textile Coloured Chemists. Containing coloured frontispiece and 9 illustrations, and 14 dyed patterns in appendix. 8vo, cloth, illustrated................*net,* $3.00

—— The Science of Color Mixing ; a manual intended for the use of Dyers, Calico Printers and Color Chemists. With figures, tables and colored plate. 8vo, cloth, illustrated......*net.* $3.00

PEIRCE, B. System of Analytic Mechanics. 4to, cloth..$10.00

—— Linear Associative Algebra. New edition with addenda and notes by C. L. Pierce. 4to, cloth $4.00

PERRINE, F. A. C., A. M., D. Sc. Conductors for Electrical Distribution ; Their Manufacture and Materials, the Calculation of Circuits, Pole Line Construction, Underground Working and other Uses...*In Press.*

PERRY, JOHN. Applied Mechanics. A Treatise for the use of students who have time to work experimental, numerical and graphical exercises illustrating the subject. 8vo, cloth, 650 pages..*net.* $2.50

PHILLIPS, JOSHUA. Engineering Chemistry. A Practical Treatise for the use of Analytical Chemists, Engineers, Iron Masters, Iron Founders, students and others. Comprising methods of Analysis and Valuation of the principal materials used in Engineering works, with numerous Analyses, Examples and Suggestions. illustrated. *Third edition, revised and enlarged.* 8vo, cloth..$4.50

PICKWORTH, CHAS. N. The Indicator Hand Book. A Practical Manual for Engineers. Part I. The Indicator: Its Construction and Application. 81 illustrations. 12mo, cloth...$1.50

PICKWORTH, CHAS. N. The Indicator Handbook. Part II. The Indicator Diagram; Its Analysis and Calculation. With tables and figures. 12mo, cloth, illustrated.............$1.50

—— **The Slide Rule. A Practical Manual of Instruction** for all Users of the Modern Type of Slide Rule, containing Succint Explanation of the Principle of Slide Rule Computation, together with Numerous Rules and Practical Illustrations, exhibiting the Application of the Instrument to the Everyday Work of the Engineer—Civil, Mechanical and Electrical. *Seventh edition.* 12mo, flexible cloth..$1.00

PLANE TABLE, The. Its Uses in Topographical Surveying. From the Papers of the United States Coast Survey. Illustrated. 8vo, cloth............................ ....$2.00
"This work gives a description of the Plane Table employed at the United States Coast Survey office, and the manner of using it."

PLANTE, GASTON. The Storage of Electrical Energy, and Researches in the Effects created by Currents, combining Quantity with High Tension. Translated from the French by Paul B. Elwell. 89 illustrations. 8vo.... ....$4.00

PLATTNER'S Manual of Qualitative and Quantitative Analysis with the Blow-Pipe. *Eighth edition, revised.* Translated by Henry B. Cornwall, E. M. Ph. D., assisted by John H. Caswell, A. M. From the sixth German edition, by Prof. Friederick Kolbeck. Illustrated with 87 woodcuts. 463 pages. 8vo, cloth. ....*net,* $4.00

PLYMPTON, Prof. GEO. W. The Aneroid Barometer: Its Construction and Use. Compiled from several sources. *Eighth edition, revised and enlarged.* 16mo, boards, illustrated......$0.50
Morocco,...$1.00

POCKET LOGARITHMS, to Four Places of Decimals, including Logarithms of Numbers, and Logarithmic Sines and Tangents to Single Minutes. To which is added a Table of Natural Sines, Tangents, and Co-Tangents. 16mo, boards............ .50

POPE, F. L. Modern Practice of the Electric Telegraph. A Technical Hand-Book for Electricians, Managers and Operators. *Fifteenth edition, rewritten and enlarged, and fully illustrated.* 8vo, cloth...................................$1.50

POPPLEWELL, W. C. Elementary Treatise on Heat and Heat Engines. Specially adapted for engineers and students of engineering. 12mo, cloth, illustrated........................$3.00

—— **Prevention of Smoke, combined with the Economical** Combustion of Fuel. With diagrams, figures and tables. 8vo, cloth, illustrated..*net,* $3.50

POWLES, H. H. Steam Boilers....................(*In Press.*)

PRAY, Jr., THOMAS. Twenty Years with the Indicator; being a Practical Text-Book for the Engineer or the Student, with no complex Formulæ. Illustrated. 8vo, cloth............$2.50

—— **Steam Tables and Engine Constant. Compiled** from Regnault, Rankine and Dixon directly, making use of the exact records. 8vo, cloth...$2.00

Practical Compounding of Oils, Tallow and Grease, for Lubrication, etc., by an Expert Oil Refiner. 8vo, cloth...*net*, $3.50

PRACTICAL IRON FOUNDING. By the author of "Pattern Making," &c., &c. Illustrated with over one hundred engravings. *Third edition.* 12mo, cloth.................... $1.50

PREECE, W. H. Electric Lamps....................(*In Press.*)

PRELINI, CHARLES., C. E. Tunneling; a Practical Treatise containing 149 Working Drawings and Figures. With additions by Charles S. Hill, C. E., Associate Editor "Engineering News." 311 pages. *Second edition, revised.* 8vo, cloth, illustrated. $3.00

PREECE, W. H., and STUBBS, A. T. Manual of Telephony. Illustrations and plates. 12mo, cloth.................$4.50

PREMIER CODE. (See Hawke, Wm. H.)

PRESCOTT, Prof. A. B. Organic Analysis. A Manual of the Descriptive and Analytical Chemistry of certain Carbon Compounds in Common Use; a Guide in the Qualitative and Quantitative Analysis of Organic Materials in Commercial and Pharmaceutical Assays, in the estimation of Impurities under Authorized Standards, and in Forensic Examinations for Poisons, with Directions for Elementary Organic Analysis. *Fifth edition.* 8vo, cloth........$5.00

—— **Outlines of Proximate Organic Analysis, for the** Identification, Separation, and Quantitative Determination of the more commonly occurring Organic Compounds. *Fourth edition.* 12mo, cloth..$1.75

PRESCOTT, A. B., and E. C. SULLIVAN. (University of Michigan). First Book in Qualitative Chemistry. For Studies of Water Solution and Mass Action. *Eleventh edition, entirely rewritten.* 12mo, cloth...................................*net*, $1.50

—— **and OTIS COE JOHNSON. Qualitative Chemical** Analysis. A Guide in the Practical Study of Chemistry and in the work of Analysis. *Fifth revised and enlarged edition, entirely rewritten.* With Descriptive Chemistry extended throughout..*net* $3.50

PRITCHARD, O. G. The Manufacture of Electric Light Carbons. Illustrated. 8vo, paper..................... .60

PULLEN, W. W. F. Application of Graphic Methods to the Design of Structures. Specially prepared for the use of Engineers. A Treatment by Graphic Methods of the Forces and Principles necessary for consideration in the Design of Engineering Structures, Roofs, Bridges, Trusses, Framed Structures, Wells, Dams, Chimneys and Masonry Structures. 12mo, cloth. Profusely Illustrated...*net*, $2.50

PULSIFER, W. H. Notes for a History of Lead. 8vo, cloth, gilt top..$4.00

PÜTSCH, ALBERT. Gas and Coal Dust Firing; a critical review of the various appliances patented in Germany for this purpose since 1885. With diagrams and figures. Translated from the German by Charles Salter. 8vo, cloth, illustrated....*net*, $3.00

PYNCHON, Prof. T. R. Introduction to Chemical Physics, designed for the use of Academies, Colleges, and High Schools. Illustrated with numerous engravings, and containing copious experiments with directions for preparing them. *New edition, revised and enlarged*, and illustrated by 269 illustrations on wood. 8vo, cloth.. $3.00

RADFORD, Lieut. CYRUS. S. Handbook on Naval Gunnery. Prepared by Authority of the Navy Department. For the use of U. S. Navy, U. S. Marine Corps and U. S. Naval Reserves. Revised and enlarged, with the assistance of Stokely Morgan, Lieut. U. S. N. *Fifth edition, revised and enlarged.* 12mo, flexible leather.. .... $2.00

RAFTER, GEO. W. and M. N. BAKER. Sewage Dis-Disposal in the United States. Illustrations and folding plates. *Third edition.* 8vo, cloth.....................................$6.00

RAM, GILBERT S. The Incandescent Lamp and its Manufacture. 8vo., cloth.....................................$3.00

RANDALL, J. E. A Practical Treatise on the Incan-descent Lamp. Illustrated. 16mo, cloth...................... .50

RANDALL, P. M. Quartz Operator's Hand-book. *New edition, revised and enlarged, fully illustrated.* 12mo, cloth...... ....$2.00

RANDAU, PAUL. Enamels and Enamelling; an introduction to the preparation and application of all kinds of enamels for technical and artistic purposes. For enamel makers, workers in gold and silver, and manufacturers of objects of art. *Third German edition.* Translated by Charles Salter. With figures, diagrams and tables. 8vo, cloth, illustrated..........................*net*. $4.00

RANKINE, W. J. MACQUORN. Applied Mechanics. Comprising the Principles of Statics and Cinematics, and Theory of Structures, Mechanism, and Machines. With numerous diagrams. *Sixteenth edition.* Thoroughly revised by W. J. Millar. 8vo, cloth... $5.00

RANKINE, W. J. MACQUORN. Civil Engineering. Comprising Engineering Surveys, Earthwork, Foundations, Masonry, Carpentry, Metal-Work, Roads, Railways, Canals, Rivers, Water-Works, Harbors, etc. With numerous tables and illustrations. *Twenty-first edition.* Thoroughly revised by W. J. Millar. 8vo, cloth..$6.50

—— **Machinery and Millwork. Comprising the Geometry,** Motions, Work, Strength, Construction, and Objects of Machines, etc. Illustrated with nearly 300 woodcuts. *Seventh edition.* Thoroughly revised by W. J. Millar. 8vo, cloth........$5.00

—— **The Steam-Engine and Other Prime Movers. With** diagram of the Mechanical Properties of Steam, folding plates, numerous tables and illustrations. *Fourteenth edition.* Thoroughly revised by W. J. Millar. 8vo, cloth..........................$5.00

—— **Useful Rules and Tables for Engineers and Others.** With appendix, tables, tests, and formulæ for the use of Electrical Engineers. Comprising Submarine Electrical Engineering, Electric Lighting, and Transmission of Power. By Andrew Jamieson, C.E., F.R.S.E. *Seventh edition.* Thoroughly revised by W. J. Millar. 8vo, cloth..$4.00

—— **A Mechanical Text Book.** By Prof. Macquorn Rankine and E. F.B amber, C. E. With numerous illustrations. *Fourth edition.* 8vo, cloth...$3.50

RAPHAEL, F. C. Localization of Faults in Electric Light Mains. 8vo, cloth $2.00

RECIPES FOR THE COLOR, Paint, Varnish, Oil, Soap and Drysaltery Trades. Compiled by an Analytical Chemist. 8vo, cloth..$3.50

RECIPES FOR FLINT GLASS MAKING. Being leaves from the mixing book of several experts in the Flint Glass Trade. Containing up-to-date recipes and valuable information as to Crystal, Demi-Crystal and Colored Glass in its many varieties. It contains the recipes for cheap metal suited to pressing, blowing, etc., as well as the most costly Cyrstal and Ruby. British manufacturers have kept up the quality of this glass from the arrival of the Venetians to Hungry Hill, Stourbridge, up to the present time. The book also contains remarks as to the result of the metal as it left the pots by the respective metal mixers, taken from their own memoranda upon the originals. Compiled by a British Glass Master and Mixer. 12mo, cloth...*net,* $4.50

RECKENZAUN, A. Electric Traction on Railways and Tramways. 213 Illustrations, 12mo, cloth...............$4.00

REED'S ENGINEERS' HAND-BOOK, to the Local Marine Board Examinations for Certificates of Competency as First and Second Class Engineers. By W. H. Thorn. With the answers to the Elementary Questions. Illustrated by 358 diagrams and 37 large plates. *Seventeenth edition, revised and enlarged.* 8vo, cloth..$5.00

REED'S Key to the Seventeenth Edition of Reed's Engineer's Hand-book to the Board of Trade Examinations for First and Second Class Engineers and containing the working of all the questions given in the examination papers. By W. H. Thorn. 8vo, cloth..$3.00

—— Useful Hints to Sea-going Engineers, and How to Repair and Avoid "Break Downs;" also Appendices Containing Boiler Explosions, Useful Formulæ, etc. With 42 diagrams and 8 plates. *Third edition, revised and enlarged.* 12mo, cloth....$1.50

—— Marine Boilers, A Treatise on the Causes and Prevention of their Priming, with Remarks on their General Management. Illustrated. 12mo, cloth..............................$2.00

REINHARDT, CHAS. W. Lettering for Draftsmen, Engineers and Students. A Practical System of Free-hand Lettering for Working Drawings. *Tenth thousand.* Oblong, boards......$1.00

—— The Technic of Mechanical Drafting. A Practical Guide to neat, correct and legible drawing, containing many illustrations, diagrams and full-page plates. 4to, cloth, illustrated... $1.00

RICE, J. M., and JOHNSON, W. W. On a New Method of obtaining the Differential of Functions, with especial reference to the Newtonian Conception of Rates or Velocities. 12mo, paper.. .50

RIDEAL, SAMUEL, D. Sc. Glue and Glue Testing, with figures and tables. 8vo, cloth, illustrated.................*net.* $4.00

RINGWALT, J. L. Development of Transportation Systems in the United States, Comprising a Comprehensive Description of the leading features of advancement from the colonial era to the present time, in water channels, roads, turnpikes, canals, railways, vessels, vehicles, cars and locomotives; the cost of transportation a various periods and places by the different methods; the financial engineering, mechanical, governmental and popular questions that have arisen, and notable incidents in railway history, construction and operation. With illustrations of hundreds of typical objects. Quarto, half morocco...$7.50

RIPPER, WILLIAM. A Course of Instruction in Machine Drawing and Design for Technical Schools and Engineer Students. With 52 plates and numerous explanatory engravings. Folio, cloth..*net,* $6.00

ROBERTSON, L. S. Water-tube Boilers. Based on a short course of Lectures delivered at University College, London. With upward of 170 illustrations and diagrams. 8vo, cloth, illustrated..$3.00

ROEBLING, J. A. Long and Short Span Railway Bridges. Illustrated with large copperplate engravings of plans and views. Imperial folio, cloth..............................$25.00

ROSE, JOSHUA, M.E. The Pattern-Makers' Assistant. Embracing Lathe Work, Branch Work, Core Work, Sweep Work, and Practical Gear Constructions, the Preparation and Use of Tools, together with a large collection of useful and valuable Tables. *Ninth edition.* Illustrated with 250 engravings. 8vo, cloth....$2.50

—— Key to Engines and Engine-running. A Practical Treatise upon the Management of Steam Engines and Boilers for the Use of Those who Desire to Pass an Examination to Take Charge of an Engine or Boiler. With numerous illustrations, and Instructions Upon Engineers' Calculations, Indicators, Diagrams, Engine Adjustments, and other Valuable Information necessary for Engineers and Firemen. 12mo, cloth..........................$2.50

SABINE, ROBERT. History and Progress of the Electric Telegraph. With descriptions of some of the apparatus. *Second edition, with additions.* 12mo, cloth..................$1.25

SAELTZER, ALEX. Treatise on Acoustics in connection with Ventilation. 12mo, cloth...........................$1.00

SALOMONS, Sir DAVID, M.A. Electric-Light Installations. A Practical Handbook. *Eighth edition, revised and enlarged with numerous illustrations.* Vol. I., The management of Accumulators. 12mo, cloth.................................... $1.50
Vol. II., Apparatus, 296 illustrations. 12mo., cloth..........$2.25
Vol. III., Applications, 12mo., cloth..........................$1.50

SANFORD, P. GERALD. Nitro-Explosives. A Practical Treatise concerning the Properties, Manufacture and Analysis of Nitrated Substances, including the Fulminates, Smokeless Powders and Celluloid. 8vo. cloth, 270 pages.....................$3.00

SAUNDERS, CHARLES H. Handbook of Practical Mechanics for use in the Shop and Draughting Room; containing tables, rules and formulas, and solutions of practical problems by simple and quick methods, 16mo, limp cloth..................$1.00

SAUNNIER, CLAUDIUS. Watchmaker's Handbook. A Workshop Companion for those engaged in Watchmaking and allied Mechanical Arts. Translated by J. Tripplin and E. Rigg. *Second edition, revised with appendix.* 12mo, cloth..........$3.50

SCHELLEN, Dr. H. Magneto-Electric and Dynamo-Electric Machines: their Construction and Practical Application to Electric Lighting, and the Transmission of Power. Translated from the third German edition by N. S. Keith and Percy Neymann, Ph.D. With very large additions and notes relating to American Machines, by N. S. Keith. Vol. 1, with 353 illustrations. *Second edition*...$5.00

SCHUMANN, F. A Manual of Heating and Ventilation in its Practical Application, for the use of Engineers and Architects. Embracing a series of Tables and Formulæ for dimensions of heating, flow and return pipes for steam and hot-water boilers, flues, etc. 12mo, illustrated, full roan..$1.50

SCIENCE SERIES, The Van Nostrand. [See List, p. 46]

SCRIBNER, J. M. Engineers' and Mechanics' Companion. Comprising United States Weights and Measures. Mensuration of Superfices and Solids, Tables of Squares and Cubes, Square and Cube Roots, Circumference and Areas of Circles, the Mechanical Powers, Centres of Gravity, Gravitation of Bodies, Pendulums, Specific Gravity of Bodies, Strength, Weight, and Crush of Materials, Water-Wheels, Hydrostatics, Hydraulics, Statics, Centres of Percussion and Gyration, Friction Heat, Tables of the Weight of Metals, Scantling, etc., Steam and the Steam-Engine. *Twenty-first edition, revised.* 16mo, full morocco................................$1.50

SEATON, A. E. A Manual of Marine Engineering. Comprising the Designing, Construction and Working of Marine Machinery. With numerous tables and illustrations reduced from Working Drawings. *Fourteenth edition.* Revised throughout, with an additional chapter on Water Tube Boilers. 8vo, cloth.......$6.00

——and ROUNTHWAITE, H. M. A Pocketbook of Marine Engineering Rules and Tables. For the use of Marine Engineers and Naval Architects, Designers, Draughtsmen, Superintendents, and all engaged in the design and construction of Marine Machinery, Naval and Mercantile. *Fifth edition, revised and enlarged.* Pocket size. Leather, with diagrams...$3.00

SEWALL, C. H. Wireless Telegraphy. With Diagrams and Figures.................................... ....*In Press.*

SEXTON, A. HUMBOLDT. Fuel and Refractory Materials. 8vo, cloth..... ....$2.00

SEXTON, A. H. Chemistry of the Materials of Engineering; a handbook for Engineering Students. With tables, diagrams and illustrations. 12mo, cloth, illustrated..............$2.50

SHAW, SIMEON. The History of the Staffordshire Potteries, and the Rise and Progress of the Manufacture of Pottery and Porcelain; with references to genuine specimens, and notices of eminent potters. A re-issue of the original work published in 1829. 8vo, cloth, illustrated..*net.* $3.00

——— Chemistry of the Several Natural and Artificial Heterogeneous Compounds used in Manufacturing Porcelain, Glass and Pottery. Re-issued in its original form, published in 1837. 8vo, cloth.. $5.00

SHELDON, Prof. S., Ph. D., and HOBART, MASON, B. S. Dynamo Electric Machinery; Its Construction, Design and Operation. Direct Current Machines. *Second edition.* 8vo, cloth, illustrated..*net.* $2.50

—— Alternating Current Machines; **being the second** volume of the author's "Dynamo Electric Machinery; its Construction, Design, and Operation." With many diagrams and figures. (Binding uniform with volume I.) 8vo, cloth, illustrated..*net,* $2.50

SHIELDS, J. E. Notes on Engineering Construction. Embracing Discussions of the Principles involved, and Descriptions of the Material employed in Tunnelling, Bridging, Canal and Road Building, etc. 12mo, cloth..$1.50

SHOCK, WM. H. Steam Boilers, Their Design, Construction and Management. 4to, half morocco................$15.00

SHREVE, S. H. A Treatise on the Strength of Bridges and Roofs. Comprising the determination of Algebraic formulas for strains in Horizontal, Inclined or Rafter, Triangular, Bowstring, Lenticular, and other Trusses, from fixed and moving loads, with practical applications, and examples, for the use of Students and Engineers. 87 woodcut illus. *Fourth edition.* 8vo, cloth....$3.50

SHUNK, W. F. The Field Engineer. A Handy Book of practice in the Survey, Location, and Truck-work of Railroads, containing a large collection of Rules and Tables, original and selected, applicable to both the Standard and Narrow Gauge, and prepared with special reference to the wants of the young Engineer. *Fourteenth edition, revised and enlarged.* 12mo, morocco, tucks....$2.50

SIMMS, F. W. A Treatise on the Principles and Practice of Levelling. Showing its application to purposes of Railway Engineering, and the Construction of Roads, etc. Revised and corrected, with the addition of Mr. Laws' Practical Examples for setting out Railway Curves. Illustrated. 8vo, cloth,..................$2.50

SIMMS, W. F. Practical Tunnelling. Fourth edition, revised and greatly extended. With additional chapters illustrating recent practice by D. Kinnear Clark. With 36 plates and other illustrations. Imperial 8vo, cloth..............................$12.00

SLATER, J. W. Sewage Treatment, Purification, and Utilization. A Practical Manual for the Use of Corporations, Local Boards, Medical Officers of Health, Inspectors of Nuisances, Chemists, Manufacturers, Riparian Owners, Engineers, and Rate-payers. 12mo, cloth...$2.25

SMITH, ISAAC W., C.E. The Theory of Deflections and of Latitudes and Departures. With special applications to Curvilinear Surveys, for Alignments of Railway Tracks. Illustrated. 16mo, morocco, tucks......................................$3.00

SMITH, J. CRUICKSHANK. Manufacture of Paint; A practical Handbook for Paint Manufacturers, Merchants and Painters. With 60 illustrations and one large diagram. 8vo, cloth, illustrated ....*net* $3.00

SNELL, ALBION T. Electric Motive Power: The Transmission and Distribution of Electric Power by Continuous and Alternate Currents. With a Section on the Applications of Electricity to Mining Work. *Second edition.* 8vo, cloth, illustrated $4.00

SPANG, HENRY W. A Practical Treatise on Lightning Protection. With figures and diagrams. 12mo, cloth....$1.00

SPEYERS, CLARENCE L. Text Book of Physical Chemistry. 8vo, cloth....................................$2.25

STAHL, A. W., and A. T. WOODS. Elementary Mechanism. A Text-Book for Students of Mechanical Engineering. *Tenth edition, enlarged.* 12mo, cloth.......................$2.00

STALEY, CADY, and PIERSON, GEO. S. The Separate System of Sewerage: its Theory and Construction. *Third edition, revised.* With maps, plates and illustrations. 8vo, cloth..$3.00

STANDAGE, H. C. Leatherworkers' Manual: being a Compendium of Practical Recipes and Working Formulæ for Curriers, Boot-makers, Leather Dressers, Blacking Manufacturers, Saddlers, Fancy Leather Workers, and all persons engaged in the manipulation of leather. 8vo, cloth................................ *net,* $3.50

STEVENSON, DAVID, F.R.S.N. The Principles and Practice of Canal and River Engineering. Revised by his sons David Alan Stevenson, B. Sc., F.R.S.E., and Charles Alexander Stevenson, B. Sc., F.R.S.E., Civil Engineer. *Third edition, with* 17 *plates.* 8vo, cloth...$10.00

—— The Design and Construction of Harbors. A Treatise on Maritime Engineering. *Third edition, with* 24 *plates.* 8vo, cloth..$9.00

STEWART, R. W. A Text Book of Light. Adapted to the Requirements of the Intermediate Science and Preliminary Scientific Examinations of the University of London, and also for General Use. Numerous Diagrams and Examples. 12mo, cloth, $1.00

—— A Text Book of Heat. Illustrated. 8vo, cloth....$1.00

—— A Text-Book of Magnetism and Electricity. 160 illus. and Numerous Examples. 12mo, cloth $1.00

—— An Elementary Text-book of Magnetism and Electricity. With numerous figures and diagrams. 12mo, cloth $1.00

STONE, ROY, GENERAL. New Roads and Road Laws in the United States. 200 pages, with numerous illustrations. 12mo, cloth $1.00

STILES, AMOS. Tables for Field Engineers. Designed for use in the field. Tables containing all the functions of a one degree curve, from which a corresponding one can be found for any required degree. Also, Tables of Natural Sines and Tangents. 12mo, morocco, tucks...$2.00

STILLMAN, PAUL. Steam-Engine Indicator and the Improved Manometer Steam and Vacuum Gauges; their Utility and Application. *New edition.* 12mo, flexible cloth.......... ...$1.00

STONEY, B. D. **The Theory of Stresses in Girders** and Similar Structures. With observations on the application of Theory to Practice, and Tables of Strength, and other properties of Materials. New revised edition, with numerous additions on Graphic Statics, Pillars, Steel, Wind Pressure, Oscillating Stresses, Working Loads, Riveting, Strength and Tests of Materials. 777 pages, 143 illustrations, and 5 folding plates. 8vo, cloth...... ....$12.50

STUART, C. B. U. S. N. **Lives and Works of Civil** and Military Engineers of America. With 10 steel-plate engravings. 8vo, cloth..$5.00

—— **The Naval Dry Docks of the United States.** Illustrated with 24 fine Engravings on Steel. *Fourth edition.* 4to, cloth...$6.00

SUFFLING, E. R. **Treatise on the Art of Glass** Painting. Prefaced with a review of ancient glass. 8vo, cloth, illustrated...*net,* $3.50

SWEET, S. H. **Special Report on Coal, showing its** Distribution, Classification, and Costs delivered over different routes to various points in the State of New York and the principal cities on the Atlantic Coast. With maps. 8vo, cloth..................$3.00

SWINTON, ALAN A. CAMPBELL. **The Elementary** Principle of Electric Lighting. Illustrated. 12mo, cloth...... .60

SWOOPE, C. WALTON. **Practical Lessons in Electricity**; Principles, Experiments and Arithmetical Problems. An Elementary Text-Book. With numerous tables, formulae and two large instruction plates. 8vo, cloth, illustrated. *Third edition.* ....*net,* $2.00

TAILFER, L. **Practical Treatise on the Bleaching of** Linen and Cotton Yarn and Fabrics. With tables and diagrams. Translated from the French by John Geddes McIntosh. 8vo, cloth, illustrated..$5.00

TEMPLETON, WM. **The Practical Mechanic's Workshop** Companion. Comprising a great variety of the most useful rules and formulæ in Mechanical Science, with numerous tables of practical data and calculated results facilitating mechanical operations. Revised and enlarged by W. S. Hutton. 12mo, morocco........$2.00

THOM, CHAS., and WILLIS H. JONES. **Telegraphic** Connections: embracing Recent Methods in Quadruplex Telegraphy. 20 full page plates, some colored. Oblong, 8vo, cloth........$1.50

THOMPSON, EDWARD P., M. E. **How to Make Inventions**; or, Inventing as a Science and an Art. A Practical Guide for Inventors. *Second edition.* 8vo, boards.................$1.00

THOMPSON, EDWARD P., M. E. Roentgen Rays and Phenomena of the Anode and Cathode. Principles, Applications and Theories. For Students, Teachers, Physicians, Photographers, Electricians and others. Assisted by Louis M. Pignolet, N. D. C. Hodges, and Ludwig Gutmann, E. E. With a Chapter on Generalizations, Arguments, Theories, Kindred Radiations and Phenomena. By Professor Wm. Anthony. 50 Diagrams, 40 Half-tones. 8vo, cloth.. $1.50

THORNLEY, T. Cotton Combing Machines. With numerous tables, engravings and diagrams. 8vo, cloth, illustrated. 343 pages.. $3.00

Contents.—Preface, List of Illustrations; The Silver Lap Machine; Ribbon Lap Machine and Draw-Frame; General Description of the Heilmann Comber; The Cam Shaft; The Detaching and Attaching Mechanism of the Comber; The Duplex Comber; Re-setting of Combers; The erection of a Heilmann Comber; Stop Motions; Various Calculations; Various Notes and Discussions; Cotton Combing Machines of Continental Make; Index.

TODD, JOHN and W. B. WHALL. Practical Seamanship for Use in the Merchant Service: Including all ordinary subjects; also Steam Seamanship, Wreck Lifting, Avoiding Collision, Wire Splicing, Displacement, and everything necessary to be known by seamen of the present day. *Second edition, with* 247 *illustrations and diagrams.* 8vo, cloth.. $8.40

TOOTHED GEARING. A Practical Hand-Book for Offices and Workshops. By a Foreman Patternmaker. 184 Illustrations. 12mo, cloth.. $2.25

TRATMAN, E. E. RUSSELL. Railway Track and Track-Work. With over two hundred illustrations. 8vo, cloth. $3.00

TRAVERSE TABLES, showing the difference of Latitude and Departure for distances between 1 and 100, and for angles to quarter degrees between 1 degree and 90 degrees. Re-printed from Scribner's Pocket Table Book. 16mo, boards. (*Van Nostrand's Science Series.* No. 115).. In press.

TREVERT, EDWARD. How to build Dynamo-Electric Machinery, embracing Theory Designing and Construction of Dynamos and Motors. With appendices on Field Magnet and Armature Winding, Management of Dynamos and Motors, and Useful Tables of Wire Gauges. Illustrated. 8vo, cloth.. $2.50

——Electricity and its Recent Applications. A Practical Treatise for Students and Amateurs, with an Illustrated Dictionary of Electrical Terms and Phrases. Illustrated. 12mo, cloth.. $2.00

TUCKER, Dr. J. H. A Manual of Sugar Analysis, including the Applications in General of Analytical Methods to the Sugar Industry. With an Introduction on the Chemistry of Cane Sugar, Dextrose, Levulose, and Milk Sugar. 8vo, cloth, illustrated.. $3.50

TUMLIRZ, Dr. O. Potential and its Application to the Explanation of Electric Phenomena, Popularly Treated. Translated from the German by D. Robertson. Ill. 12mo, cloth....$1.25

TUNNER, P. A. Treatise on Roll-Turning for the Manufacture of Iron. Translated and adapted by John B. Pearse, of the Pennsylvania Steel Works, with numerous engravings, woodcuts. 8vo, cloth, with folio atlas of plates..........................$10.00

URQUHART, J. W. Electric Light Fitting. Embodying Practical Notes on Installation Management. A Hand-book for Working Electrical Engineers. With numerous illustrations. 12mo, cloth...$2.00

—— Electro-Plating. A Practical Hand Book on the Deposition of Copper, Silver, Nickel, Gold, Brass, Aluminium, Platininum, etc. *Third edition.* 12mo..........................$2.00

—— Electrotyping; A Practical Manual forming a New and Systematic Guide to the Reproduction and Multiplication of Printing Surfaces, etc. 12mo..................................$2.00

URQUHART, J. W. Dynamo Construction: a Practical Hand-Book for the Use of Engineer Constructors and Electricians in Charge, embracing Frame Work Building, Field Magnet and Armature Winding and Grouping, Compounding, etc., with Examples of Leading English, American and Continental Dynamos and Motors, with numerous illustrations. 12mo, cloth.....................$3.00

—— Electric Ship Lighting. A Hand-Book on the Practical Fitting and Running of Ship's Electrical Plant. For the Use of Ship Owners and Builders, Marine Electricians and Sea Going Engineers-in-Charge. Numerous illustrations. 12mo, cloth......$3.00

UNIVERSAL TELEGRAPH CIPHER CODE. Arranged for General Correspondence. 12mo, cloth..............$1.00

VAN NOSTRAND'S Engineering Magazine. Complete sets, 1869 to 1886 inclusive.

Complete sets, 35 vols., in cloth.............................$60.00

Complete sets, 35 vols., in half morocco..................... 100.00

VAN WAGENEN, T. F. Manual of Hydraulic Mining. For the Use of the Practical Miner. *Revised and enlarged edition.* 18mo, cloth..$1.00

VILLON, A. M. Practical Treatise on the Leather Industry. With many tables and illustrations and a copious index. A translation of Villon's "Traite Pratique de la Fabrication des Cuirs et du Travail des Peaux," by Frank T. Addyman, B. Sc. 8vo, cloth, illustrated...$10.00

VINCENT, CAMILLE. Ammonia and its Compounds; their Manufacture and Uses. Translated from the French by M. J. Salter. 8vo, cloth, illustrated.................*net,* $2.00

VON GEORGIEVICS, GEORG. Chemical Technology of Textile Fibres; Their Origin, Structure, Preparation, Washing, Bleaching, Dyeing, Printing, and Dressing. Translated from the German by Charles Salter. With many diagrams and figures. 8vo, cloth, illustrated. 306 pages.....................................$4.50

Contents.—The Textile Fibres; Washing, Bleaching and Carbonizing; Mordants and Mordanting; Dyeing, Printing, Dressing and Finishing; Index.

WALKER, W. H. Screw Propulsion. Notes on Screw Propulsion, its Rise and History. 8vo, cloth.................. .75

WALKER, SYDNEY F. Electrical Engineering in Our Homes and Workshops. A Practical Treatise on Auxiliary Electrical Apparatus. *Third edition, revised, with numerous illustrations*..$2.00

—— Electric Lighting for Marine Engineers, or How to Light a Ship by the Electric Light and How to Keep the Apparatus in Order. 103 illustrations. 8vo, cloth. *Second edition*.......$2.00

WALLIS-TAYLER, A. J. Modern Cycles, A Practical Handbook on Their Construction and Repair. With 300 illustrations. 8vo, cloth...$4.00

—— Motor Cars, or Power Carriages for Common Roads. With numerous illustrations. 8vo, cloth..............$1.80

—— Bearings and Lubrication. A Handbook for every user of Machinery. Fully illustrated. 8vo, cloth..............$1.50

—— Refrigerating and Ice-Making Machinery. A Descriptive Treatise for the use of persons employing refrigerating and ice-making installations and others. 8vo, cloth, illustrated..$3.00

—— Refrigeration and Cold Storage; being a complete practical treatise on the art and science of refrigeration. 600 pp., 361 diagrams and figures. 8vo, cloth, illustrated..........*net*, $4.50

—— Sugar Machinery. A Descriptive Treatise, devoted to the Machinery and Apparatus used in the Manufacture of Cane and Beet Sugars. 12mo, cloth, ill...........................$2.00

WANKLYN, J. A. A Practical Treatise on the Examination of Milk and its Derivatives, Cream, Butter, and Cheese. 12mo, cloth...$1.00

—— Water Analysis. A Practical Treatise on the Examination of Potable Water. *Tenth edition.* 12mo, cloth.....$2.00

WANSBROUGH, WM. D. The A. B. C. of the Differential Calculus. 12mo, cloth...............................$1.50

WARD, J. H. Steam for the Million. A Popular Treatise on Steam, and its application to the Useful Arts, especially to Navigation. 8vo, cloth..... ....$1.00

WARING, GEO. E., Jr. Sewerage and Land Drainage. Illustrated with wood-cuts in the text, and full-page and folding plates. Quarto. Cloth. *Third edition*.....................$6.00

—— Modern Methods of Sewage Disposal for Towns, Public Institutions and Isolated Houses. *Second edition, revised and enlarged.* 260 pages. Illustrated. cloth.................$2.00

—— How to Drain a House. Practical Information for Householders. *Third edition enlarged.* 12mo, cloth..........$1.25

WATSON, E. P. Small Engines and Boilers. A manual of Concise and Specific Directions for the Construction of Small Steam Engines and Boilers of Modern Types from five Horse-power down to model sizes. Illustrated with Numerous Diagrams and Half Tone Cuts. 12mo, cloth.....................................$1.25

WATT, ALEXANDER. Electro-Deposition. A Practical Treatise on the Electrolysis of Gold, Silver, Copper, Nickel, and other Metals, with Descriptions of Voltaic Batteries, Magneto and Dynamo-Electric Machines, Thermopiles, and of the Materials and Processes used in every Department of the Art, and several chapters on Electro-Metallurgy. With numerous illustrations. *Third edition, revised and corrected. New and enlarged edition........In Press.*

—— Electro-Metallurgy Practically Treated. *Eleventh edition, considerably enlarged.* 12mo, cloth.................. $1.00

—— The Art of Soap-Making. A Practical Handbook of the Manufacture of Hard and Soft Soaps, Toilet Soaps, &c. Including many New Processes, and a Chapter on the Recovery of Glycerine from Waste Lyes. With illustrations. *Fifth edition, revised and enlarged.* 8vo, cloth...........................$3.00

WATT, ALEXANDER. The Art of Leather Manufacture. Being a Practical Handbook, in which the Operations of Tanning, Currying, and Leather Dressing are Fully Described, and the Principles of Tanning Explained, and many Recent Processes Introduced. With numerous illustrations. *Second edition.* 8vo, cl.$4.00

WEALE, JOHN. A Dictionary of Terms Used in Architecture, Building, Engineering, Mining, Metallurgy, Archaelogy, the Fine Arts, etc., with explanatory observations connected with applied Science and Art. *Fifth edition, revised and corrected.* 12mo, cloth..$2.50

WEBB, HERBERT LAWS. A Practical Guide to the Testing of Insulated Wires and Cables. Illustrated. 12mo, cloth...$1.00

—— The Telephone Hand Book. 128 illustrations. 146 pages. 16mo., cloth.......................................$1.00

WEEKES, R. W. The Design of Alternate Current Transformers. Illustrated. 12mo, cloth.....................$1.00

WEISBACH, JULIUS. A Manual of Theoretical Mechanics. Ninth American edition. Translated from the fourth augmented and improved German edition, with an Introduction to the Calculus by Eckley B. Coxe, A.M., Mining Engineer. 1,100 pages, and 902 woodcut illustrations. 8vo, cloth............ $6.00
Sheep.. 7.50

WESTON, EDMUND B. Tables Showing Loss of Head Due to Friction of Water in Pipes. *Second edition.* 12mo, cloth...$1.50

WEYMOUTH, F. MARTEN. Drum Armatures and Commutators. (Theory and Practice.) A complete Treatise on the Theory and Construction of Drum Winding, and of commutators for closed-coil armatures, together with a full resume of some of the principal points involved in their design, and an exposition of armature re-actions and sparking. 8vo, cloth $3.00

WHEELER, Prof, J. B. Art of War. A Course of Instruction in the Elements of the Art and Science of War, for the Use of the Cadets of the United States Military Academy, West Point, N. Y. 12mo, cloth...$1.75

—— **Field Fortifications. The Elements of Field** Fortifications, for the Use of the Cadets of the United States Military Academy, West Point, N. Y. 12mo, cloth.....................$1.75

WHIPPLE, S., C. E. An Elementary and Practical Treatise on Bridge Building. 8vo, cloth......................$3.00

WHITE, W. H., K. C. B. A Manual of Naval Architecture, for use of Officers of the Royal Navy, Officers of the Merchantile Marine, Yachtsmen, Shipowners and Shipbuilders. Containing many figures, diagrams and tables. Thick, 8vo, cloth, illus......$9.00

WILKINSON, H. D. Submarine Cable-Laying, Repairing and Testing. 8vo, cloth.............................$5.00

WILLIAMSON, R. S. On the Use of the Barometer on Surveys and Reconnoissances. Part I. Meteorology in its Connection with Hypsometry. Part II. Barometric Hypsometry. With Illustrative tables and engravings. 4to, cloth.....................$15.00

—— **Practical Tables in Meteorology and Hypsometry,** in connection with the use of the Barometer. 4to, cloth..... $2.50

WILSON, GEO. Inorganic Chemistry, with New Notation. Revised and enlarged by H. G. Madan. *New edition.* 12mo, cloth..$2.00

WINKLER, CLEMENS. Handbook of Technical Gas-Analysis. With figures and diagrams. Second English Edition, Translated from the Third, greatly enlarged German Edition, with some additions by George Lunge, Ph. D. 8vo, cloth, illustrated, 190 pages...$4.00

WOODBURY, D. V. Treatise on the Various Elements of Stability in the Well-Proportioned Arch. 8vo, half morocco..$4.00

WRIGHT, T. W., PROF. (*Union College*). **Elements of** Mechanics; including Kinematics, Kinetics and Statics. With applications. *Third edition, revised and enlarged.* 8vo, cloth.. $2.50

WYLIE, CLAUDE. Iron and Steel Founding. Illustrated with 39 diagrams. *Second edition, revised and enlarged.* 8vo, cloth.............................. ....$2.00

WYNKOOP, RICHARD. Vessels and Voyages, as Regulated by Federal Statutes and Treasury Instructions and Decisions. 8vo, cloth $2.00

YOUNG, J. ELTON. Electrical Testing for Telegraph Engineers. With Appendices consisting of Tables. 8vo, cloth, illustrated...$4.00

YOUNG SEAMAN'S MANUAL. Compiled from Various Authorities, and Illustrated with Numerous Original and Select Designs, for the Use of the United States Training Ships and the Marine Schools. 8vo, half roan $3.00

ZIPSER, JULIUS. Textile Raw Materials, and their Conversion into Yarns. The study of the Raw Materials and the Technology of the Spinning Process. A Text-book for Textile, Trade and higher Technical Schools, as also for self-instruction. Based upon the ordinary syllabus and curriculum of the Imperial and Royal Weaving Schools. Translated from the German by Chas. Salter. 8vo, cloth, illustrated....................................$5.00

Catalogue of the Van Nostrand Science Series.

THEY are put up in a uniform, neat, and attractive form. 18mo, boards. Price 50 cents per volume. The subjects are of an eminently scientific character, and embrace a wide range of topics, and are amply illustrated when the subject demands.

No. 1. CHIMNEYS FOR FURNACES AND STEAM-BOILERS. By R. Armstrong, C.E. Third American edition, revised and partly rewritten, with an appendix on Theory of Chimney Draught, by F. E. Idell, M.E.

No. 2. STEAM-BOILER EXPLOSIONS. By Zerah Colburn. New edition, revised by Prof. R. H. Thurston.

No. 3. PRACTICAL DESIGNING OF RETAINING-WALLS. By Arthur Jacob, A.B. Second edition, revised, with additions by Prof. W. Cain.

No. 4. PROPORTIONS OF PINS USED IN BRIDGES. Second edition, with appendix. By Charles E. Bender, C.E.

No. 5. VENTILATION OF BUILDINGS. By W. F. Butler. Second edition, re-edited and enlarged by James L. Greenleaf, C.E.

No. 6. ON THE DESIGNING AND CONSTRUCTION OF STORAGE RESERVOIRS. By Arthur Jacob, A.B. Second edition, revised, with additions by E. Sherman Gould.

No. 7. SURCHARGED AND DIFFERENT FORMS OF RETAINING-WALLS. By James S. Tate, C.E.

No. 8. A TREATISE ON THE COMPOUND ENGINE. By John Turnbull, jun. Second edition, revised by Prof. S. W. Robinson.

No. 9. A TREATISE ON FUEL. By Arthur V. Abbott, C. E. Founded on the original treatise of C. William Siemens, D.C.L.

No. 10. COMPOUND ENGINES. Translated from the French of A. Mallet. Second edition, revised, with Results of American Practice, by Richard H. Buel, C.E.

No. 11. THEORY OF ARCHES. By Prof. W. Allan.

No. 12. A THEORY OF VOUSSOIR ARCHES. By Prof. W. E. Cain. Second edition, revised and enlarged. Illustrated.

No. 13. GASES MET WITH IN COAL-MINES. By J. J. Atkinson. Third edition, revised and enlarged by Edward H. Williams, jun.

No. 14. FRICTION OF AIR IN MINES. By J. J. Atkinson.

No. 15. SKEW ARCHES. By Prof. E. W. Hyde, C.E. Illustrated.

No. 16. A GRAPHIC METHOD OF SOLVING CERTAIN QUESTIONS IN ARITHMETIC OR ALGEBRA. By Prof. Geo. L. Vose.

No. 17. WATER AND WATER-SUPPLY. By Prof. W. H. Corfield of the University College, London.

No. 18. SEWERAGE AND SEWAGE PURIFICATION. By M. N. Baker, Assoc. Ed. *Engineering News.*

No. 19. STRENGTH OF BEAMS UNDER TRANSVERSE LOADS. By Prof. W. Allan, author of "Theory of Arches."

No. 20. BRIDGE AND TUNNEL CENTRES. By John B. McMaster, C.E.

No. 21. SAFETY VALVES. By Richard H. Buel, C.E. Third edition.

No. 22. HIGH MASONRY DAMS. By E. Sherman Gould, C.E.

No. 23. THE FATIGUE OF METALS UNDER RKPEATED STRAINS. With Various Tables of Results and Experiments. From the German of Prof. Ludwig Spangenburgh, with a Preface by S. H. Shreve, A.M.

No. 24. A PRACTICAL TREATISE ON THE TEETH OF WHEELS. By Prof. S. W. Robinson. Second edition, revised.

No. 25. ON THE THEORY AND CALCULATION OF CONTINUOUS BRIDGES. By R. M. Wilcox, Ph.B.

No. 26. PRACTICAL TREATISE ON THE PROPERTIES OF CONTINUOUS BRIDGES By Charles Bender, C.E.

No. 27. ON BOILER INCRUSTATION AND CORROSION By F. J. Rowan. New edition, revised and partly rewritten by F. E. Idell, M. E.

No. 28. TRANSMISSION OF POWER BY WIRE ROPES By Albert W. Stahl, U.S.N. Second edition.

No. 29. STEAM INJECTORS. Translated from the French of M. Leon Pochet.

No. 30. TERRESTRIAL MAGNETISM, AND THE MAGNETISM OF IRON VESSELS. By Prof. Fairman Rogers.

No. 31. THE SANITARY CONDITION OF DWELLING-HOUSES IN TOWN AND COUNTRY. By George E. Waring, jun.

No. 32. CABLE-MAKING FOR SUSPENSION BRIDGES. By W. Hildenbrand, C.E.

No. 33. MECHANICS OF VENTILATION. By George W. Rafter, C.E. New edition (1895), revised by author.

No. 34. FOUNDATIONS. By Prof. Jules Gaudard, C.E. Translated from the French.

No. 35. THE ANEROID BAROMETER: ITS CONSTRUCTION AND USE. Compiled by George W. Plympton. Eighth edition.

No. 36. MATTER AND MOTION. By J. Clerk Maxwell, M.A. Second American edition.

No. 37. **GEOGRAPHICAL SURVEYING: ITS USES, METHODS, AND RESULTS.** By Frank De Yeaux Carpenter, C.E.

No. 38. **MAXIMUM STRESSES IN FRAMED BRIDGES.** By Prof. William Cain, A.M., C.E. New and revised edition.

No. 39. **A HANDBOOK OF THE ELECTRO-MAGNETIC TELEGRAPH.** By A. E. Loring. New enlarged edition.

No. 40. **TRANSMISSION OF POWER BY COMPRESSED AIR.** By Robert Zahner, M.E. Second edition.

No. 41. **STRENGTH OF MATERIALS.** By William Kent, C.E., Assoc. Ed. Engineering News.

No. 42. **THEORY OF STEEL-CONCRETE ARCHES AND OF VAULTED STRUCTURES.** By Prof. William Cain.

No. 43. **WAVE AND VORTEX MOTION.** By Dr. Thomas Craig of Johns Hopkins University.

No. 44. **TURBINE WHEELS.** By Prof. W. P. Trowbridge, Columbia College. Second edition.

No. 45. **THERMODYNAMICS.** By Prof. H. T. Eddy, University of Cincinnati.

No. 46. **ICE-MAKING MACHINES.** New edition, revised and enlarged by Prof. J. E. Denton. From the French of M. Le Doux.

No. 47. **LINKAGES; THE DIFFERENT FORMS AND USES OF ARTICULATED LINKS.** By J. D. C. de Roos.

No. 48. **THEORY OF SOLID AND BRACED ARCHES.** By William Cain, C.E.

No. 49. **ON THE MOTION OF A SOLID IN A FLUID.** By Thomas Craig, Ph.D.

No. 50. **DWELLING-HOUSES: THEIR SANITARY CONSTRUCTION AND ARRANGEMENTS.** By Prof. W. H. Corfield.

No. 51. **THE TELESCOPE: ITS CONSTRUCTION, ETC.** By Thomas Nolan.

No. 52. **IMAGINARY QUANTITIES.** Translated from the French of M. Argand. By Prof. Hardy.

No. 53. **INDUCTION COILS: HOW MADE AND HOW USED.** Third American, from Ninth English edition.

No. 54. **KINEMATICS OF MACHINERY.** By Prof. Kennedy. With an introduction by Prof. R. H. Thurston.

No. 55. **SEWER GASES: THEIR NATURE AND ORIGIN.** By A. de Varona.

No. 56. **THE ACTUAL LATERAL PRESSURE OF EARTHWORK.** By Benjamin Baker, M. Inst. C.E.

No. 57. **INCANDESCENT ELECTRIC LIGHTING.** A Practical Description of the Edison System. By L. H. Latimer, to which is added the Design and Operation of Incandescent Stations, by C. J. Field, and the Maximum Efficiency of Incandescent Lamps, by John W. Howell.

No. 58. **THE VENTILATION OF COAL-MINES.** By W. Fairley. M.E., F.S.S.

No. 59. RAILROAD ECONOMICS; OR, NOTES, WITH COMMENTS. By S. W. Robinson, C.E.

No. 60. STRENGTH OF WROUGHT-IRON BRIDGE MEMBERS. By S. W. Robinson, C.E.

No. 61. POTABLE WATER AND METHODS OF DETECTING IMPURITIES. By M. N. Baker, Ph.B.

No. 62. THE THEORY OF THE GAS-ENGINE. By Dugald Clerk. Second edition. With additional matter. Edited by F. E. Idell, M.E.

No. 63. HOUSE DRAINAGE AND SANITARY PLUMBING. By W. P. Gerhard. Eighth edition, revised.

No. 64. ELECTRO-MAGNETS. By A. N. Mansfield, S.B.

No. 65. POCKET LOGARITHMS TO FOUR PLACES OF DECIMALS.

No. 66. DYNAMO-ELECTRIC MACHINERY. By S. P. Thompson With notes by F. L. Pope. Third edition.

No. 67. HYDRAULIC TABLES BASED ON "KUTTER'S FORMULA." By P. J. Flynn.

No. 68. STEAM-HEATING. By Robert Briggs. Third edition, revised, with additions by A. R. Wolff.

No. 69. CHEMICAL PROBLEMS. By Prof. J. C. Foye. Fourth edition, revised and enlarged.

No. 70. EXPLOSIVE MATERIALS. The Phenomena and Theories of Explosion, and the Classification, Constitution and Preparation of Explosives. By First Lieut. John P. Wisser, U.S.A.

No. 71. DYNAMIC ELECTRICITY. By John Hopkinson, J. N. Shoolbred, and R. E. Day.

No. 72. TOPOGRAPHICAL SURVEYING. By George J. Specht, Prof. A. S. Hardy, John B. McMaster, and H. F. Walling.

No. 73. SYMBOLIC ALGEBRA; OR, THE ALGEBRA OF ALGEBRAIC NUMBERS. By Prof. W. Cain.

No. 74. TESTING MACHINES: THEIR HISTORY, CONSTRUCTION, AND USE. By Arthur V. Abbott.

No. 75. RECENT PROGRESS IN DYNAMO-ELECTRIC MACHINES. Being a Supplement to Dynamo-Electric Machinery. By Prof. Sylvanus P. Thompson.

No. 76. MODERN REPRODUCTIVE GRAPHIC PROCESSES. By Lieut. James S. Pettit, U.S.A.

No. 77. STADIA SURVEYING. The Theory of Stadia Measurements. By Arthur Winslow.

No. 78. THE STEAM-ENGINE INDICATOR, AND ITS USE. By W. B. Le Van.

No. 79. THE FIGURE OF THE EARTH. By Frank C. Roberts, C.E.

No. 80. HEALTHY FOUNDATIONS FOR HOUSES. By Glenn Brown.

SCIENCE SERIES.

No. 81. **WATER METERS: COMPARATIVE TESTS OF** ACCURACY, DELIVERY, ETC. Distinctive features of the Worthington, Kennedy, Siemens, and Hesse meters. By Ross E. Browne.

No. 82. **THE PRESERVATION OF TIMBER BY THE USE** OF ANTISEPTICS. By Samuel Bagster Boulton, C.E.

No. 83. **MECHANICAL INTEGRATORS.** By Prof. Henry S. H. Shaw, C.E.

No. 84. **FLOW OF WATER IN OPEN CHANNELS, PIPES,** CONDUITS, SEWERS, ETC. With Tables. By P. J. Flynn, C.E.

No. 85. **THE LUMINIFEROUS ÆTHER.** By Prof. de Volson Wood.

No. 86. **HAND-BOOK OF MINERALOGY; DETERMINATION** AND DESCRIPTION OF MINERALS FOUND IN THE UNITED STATES. By Prof. J. C. Foye.

No. 87. **TREATISE ON THE THEORY OF THE CON-** STRUCTION OF HELICOIDAL OBLIQUE ARCHES. By John L. Culley, C.E.

No. 88. **BEAMS AND GIRDERS.** Practical Formulas for their Resistance. By P. H. Philbrick.

No. 89. **MODERN GUN-COTTON: ITS MANUFACTURE,** PROPERTIES, AND ANALYSIS. By Lieut. John P. Wisser, U.S.A.

No. 90. **ROTARY MOTION, AS APPLIED TO THE GYRO-** SCOPE. By Gen. J. G. Barnard.

No. 91. **LEVELING: BAROMETRIC, TRIGONOMETRIC, AND** SPIRIT. By Prof. I. O. Baker.

No. 92. **PETROLEUM: ITS PRODUCTION AND USE.** By Boverton Redwood, F.I.C., F.C.S.

No. 93. **RECENT PRACTICE IN THE SANITARY DRAIN-** AGE OF BUILDINGS. With Memoranda on the Cost of Plumbing Work. Second edition, revised. By William Paul Gerhard, C. E.

No. 94. **THE TREATMENT OF SEWAGE.** By Dr. C. Meymott Tidy.

No. 95. **PLATE GIRDER CONSTRUCTION.** By Isami Hiroi, C.E. Second edition, revised and enlarged. Plates and Illustrations.

No. 96. **ALTERNATE CURRENT MACHINERY.** By Gisbert Kapp, Assoc. M. Inst., C.E.

No. 97. **THE DISPOSAL OF HOUSEHOLD WASTE.** By W. Paul Gerhard, Sanitary Engineer.

No. 98. **PRACTICAL DYNAMO-BUILDING FOR AMATEURS.** HOW TO WIND FOR ANY OUTPUT. By Frederick Walker. Fully illustrated.

No. 99. **TRIPLE-EXPANSION ENGINES AND ENGINE** TRIALS. By Prof. Osborne Reynolds. Edited, with notes, etc., by F. E. Idell, M. E.

No. 100. HOW TO BECOME AN ENGINEER; OR, THE THEORETICAL AND PRACTICAL TRAINING NECESSARY IN FITTING FOR THE DUTIES OF THE CIVIL ENGINEER. The Opinions of Eminent Authorities, and the Course of Study in the Technical Schools. By Geo. W. Plympton, Am. Soc. C.E.

No. 101. THE SEXTANT AND OTHER REFLECTING MATHEMATICAL INSTRUMENTS. With Practical Suggestions and Wrinkles on their Errors, Adjustments, and Use. With thirty-three illustrations. By F. R. Brainard, U.S.N.

No. 102. THE GALVANIC CIRCUIT INVESTIGATED MATHEMATICALLY. By Dr. G. S. Ohm, Berlin, 1827. Translated by William Francis. With Preface and Notes by the Editor, Thomas D. Lockwood, M.I.E.E.

No. 103. THE MICROSCOPICAL EXAMINATION OF POTABLE WATER. With Diagrams. By Geo. W. Rafter.

No. 104. VAN NOSTRAND'S TABLE-BOOK FOR CIVIL AND MECHANICAL ENGINEERS. Compiled by Geo. W. Plympton, C.E.

No. 105. DETERMINANTS, AN INTRODUCTION TO THE STUDY OF. With examples. By Prof. G. A. Miller.

No. 106. TRANSMISSION BY AIR-POWER. Illustrated. By Prof. A. B. W. Kennedy and W. C. Unwin.

No. 107. A GRAPHICAL METHOD FOR SWING-BRIDGES. A Rational and Easy Graphical Analysis of the Stresses in Ordinary Swing-Bridges. With an Introduction on the General Theory of Graphical Statics. 4 Plates. By Benjamin F. LaRue, C.E.

No. 108. A FRENCH METHOD FOR OBTAINING SLIDE-VALVE DIAGRAMS. 8 Folding Plates. By Lloyd Bankson, B.S., Assist. Naval Constructor, U.S.N.

No. 109. THE MEASUREMENT OF ELECTRIC CURRENTS. ELECTRICAL MEASURING INSTRUMENTS. By Jas. Swinburne. METERS FOR ELECTRICAL ENERGY. By C. H. Wordingham. Edited by T. Commerford Martin. Illustrated.

No. 110. TRANSITION CURVES. A Field Book for Engineers, containing Rules and Tables for laying out Transition Curves. By Walter G. Fox.

No. 111. GAS-LIGHTING AND GAS-FITTING, including Specifications and Rules for Gas Piping, Notes on the Advantages of Gas for Cooking and Heating, and useful Hints to Gas Consumers. Second edition, rewritten and enlarged. By Wm. Paul Gerhard.

No. 112. A PRIMER ON THE CALCULUS. By E. Sherman Gould, C.E.

No. 113. PHYSICAL PROBLEMS AND THEIR SOLUTION. By A. Bourgougnon, formerly Assistant at Bellevue Hospital.

No. 114. MANUAL OF THE SLIDE RULE. By F. A. Halsey of the American Machinist. Second edition, revised.

No. 115. TRAVERSE TABLES, showing the difference of Latitude and Departure for distances between 1 and 100 and for Angles to Quarter Degrees between 1 degree and 90 degrees. (Reprinted from Scribner's Pocket Table Book.)

No. 116. WORM AND SPIRAL GEARING. Reprinted from "American Machinist." By F. A. Halsey.

Catalogue of Weale's Rudimentary

Scientific Series.

☞ "**WEALE'S SERIES includes Text-Books on almost every branch of Science and Industry, comprising such subjects as Architecture and Building, Civil Engineering, Fine Arts, Mechanics and Mechanical Engineering, Physical and Chemical Science, and many miscellaneous Treatises. The whole are constantly undergoing revision, and new editions, brought up to the latest discoveries in scientific research, are constantly issued. We carry large stocks and can furnish nearly all the series on orders. Such as are not in stock can be procured promptly.**"

No.		Price.
1.	**Chemistry, by Fownes**	$
2.	**Natural Philosophy, by Tomlinson**	.60
4.	**Mineralogy, by Ramsay. 3d edition, enlarged**	1.40
6.	**Mechanics, by Tomlinson**	.60
7.	**Electricity, by Harris**	
7*.	**Galvanism and Electricity, by Harris**	
8.	**Rudimentary Magnetism, by Harris and Noad**	
11.	**Electric Telegraph, History, by Sabine**	
12.	**Pneumatics, Acoustics, &c., by Chas. Tomlinson, F.R.S. 4th Edition, enlarged**	.60
16.	**Architecture, Orders, by Leeds**	.60
17.	**Architecture, Styles, by Bury**	.80
16.	**17, bound together**	1.40
18.	**Architecture, Design, by Garbett**	1.00
16.	**17, and 18, in one vol. half-bound**	2.40
20.	**Perspective, by Pyne**	.80
22.	**Building, Art of, by Dobson**	.80
23.	**Brick and Tile Making, by Dobson**	1.20
25.	**Masonry and Stone Cutting, by Dobson**	1.00
31.	**Well-Sinking. By Swindell and Burnell**	.80
32.	**Mathematical Instruments, by Heather. New Edition, enlarged by A. T. Walmisley**	.80

No.		Price.
33.	Cranes and Machinery, by Glynn	$0.60
34.	Steam Engine, by Lardner	.60
35.	Blasting and Quarrying, by Burgoyne	.60
36.	Dictionary of Terms in Architecture, &c., by John Weale. Enlarged by Robert Hunt, F.R.S.	2.00
40.	Glass Staining and Painting on Glass, by Gessert and Fromberg	1.00
42.	Cottage Building, by C. Bruce Allen	.80
43.	Tubular and Girder Bridges, by Dempsey	.80
44.	Foundations and Concrete Work, by Dobson	.60
45.	Limes, Cements, Mortars, &c., by Burnell	.60
50.	Law of Contracts, by Gibbons	
51.	Naval Architecture, by Peake	1.40
53*	Ships, Construction of, by Sommerfeldt	.60
53**.	Plates to ditto, 4to	3.00
54.	Masting and Rigging, by Kipping	.80
54*.	Iron Ship Building, by Grantham	
55.	Navigation ("The Sailor's Sea Book"), by Greenwood. New Edition by W. H. Rosser	1.00
57.	Warming and Ventilation, by Tomlinson	
59.	Steam Boilers, by Armstrong	.60
60.	Land and Engineering Surveying, by Baker	.80
61*	Ready Reckoner for Land, by Arman	.80
67.	Clocks and Watches, and Bells, by Sir E. Beckett. 7th Edition, revised and enlarged	1.80
69.	Music, by Spencer	1.00
71.	Pianoforte Instruction, by Spencer	.60
69 & 71.	Music and the Pianoforte, by Spencer. In 1 vol. half-bound	
72.	Recent and Fossil Shells, by Woodward	
76.	Geometry, Descriptive, by Heather	.80
80.	Marine Engines, by Murray. 8th Edition, with Additions by G. Carlisle, C.E	1.80
80*	Embanking Lands from the Sea, by Wiggins	
81.	Water Works, by Hughes	1.60
83**.	Locks, Construction of	1.00
83.	(*bis*). Ships and Boats, by Bland	.60
83.	Book-keeping, Haddon	.60
84.	Arithmetic, by Young	.60
84*.	Key to ditto	.60
85.	Equational Arithmetic, by Hipsley	.60
86.	Algebra, by Haddon	.80
86*.	Key to ditto	.60
88.	Geometry. Part I. (Euclid, Books I.—III.) By Law	.60

SCIENTIFIC PUBLICATIONS.

No.		Price.
89.	——— Part II. (Euclid, Books IV., V., VI., XI., XII.) By Law	$0.60
88. 89.	Geometry, in 1 vol. (Euclid's Elements.)	1.00
90.	Analytical Geometry, by Hann and Young	.80
91.	Plane Trigonometry, by Hann	.60
92.	Spherical Trigonometry, by Hann	.40
91, 92,	bound together	1.00
93.	Mensuration and Measuring, by Baker	.60
96.	Astronomy, by Main. Revised by W. T. Lynn	.80
97.	Statics and Dynamics, by Baker	.60
98.	Mechanism and Machines, by Baker and Nasmyth	1.00
99.	Navigation and Nautical Astronomy, by Young	1.00
101.	Differential Calculus, by Woolhouse	.60
102.	Integral Calculus, by Cox	.60
106.	Ships' Anchors, by Cotsell	
111.	Arches, Piers and Buttresses, by Bland	.60
112.	Domestic Medicines, by Gooding	.80
112*.	The Management of Health, by Baird	.40
113.	On the Use of Field Artillery, by H. H. Maxwell	
113.*	Memoir on Swords, by Col. Marey	
116.	Acoustics of Public Buildings, by Smith	.60
117.	Subterraneous Surveying, by Fenwick and Baker	1.00
118.	Civil Engineering in North America, by Stevenson	
127.	Architectural Modeling, by Richardson	.60
128.	Vitruvius' Architecture, by Gwilt	2.00
130.	Grecian Architecture, by Lord Aberdeen	.40
128, 130,	in 1 vol. half-bound	2.40
131.	Miller's, Corn Merchant's and Farmer's Ready Reckoner. Revised by Hutton	.80
132.	Dwelling Houses, Erection of, by Brooks	1.00
135.	Electro-metallurgy, Watt	1.40
136.	Arithmetic, by Haddon	.60
137.	Key to ditto	
138.	Telegraph, Handbook of, by Bond	
139.	Steam Engine, Theory of, by Baker	.60
140.	Farming—Soils, Manures and Crops, by Burn	.80
141.	Ditto Outlines—Farming Economy, by Burn	1.20
142.	Ditto Cattle, Sheep and Horses, by Burn	1.00
143.	Experimental Essays, by C. Towlinson	
145.	Farming, Dairy, Pigs, and Poultry, by Burn	.80
146.	Ditto Sewage, Irrigation, &c., by Burn	1.00
140 to 146.	The 5 vols. in 1, half-bound	4.80
147.	The Stepping Stone to Arithmetic, by A. Arman	
148.	Key to the same	

No.		Price.
149.	Sails and Sailmaking, by Kipping	$1.00
150.	Logic, by Emmens	.60
151.	Handy Book on the Law of Friendly, Industrial and Provident Building and Loan Societies, by A. White	
153.	Locke on the Understanding, by Emmens	.60
154.	General Hints to Emigrants	
155.	Engineer's Guide to the Navies	
156.	Quantities and Measurements, by Beaton	.60
157.	Emigrant's Guide to Natal, by Dr. Mann	
158.	Slide Rule and How to Use it, by Hoare	1.00
162.	Brass Founder's Manual, by W. Graham	.80
163.	Law of Patents for Invention, by F. W. Campin	
164.	Modern Workshop Practice, by J. G. Winton. Fourth Edition, revised and enlarged	1.40
165.	Iron and Heat, by Armour	1.00
166.	Power in Motion, by Armour	.80
167.	Iron Bridges, Girders, &c., by Campin	
168.	Drawing and Measuring Instruments, by Heather	.60
169.	Optical Instruments, by Heather	.60
170.	Surveying and Astronomical Instruments, by Heather	.60
168, 169, 170.	The three parts as above in 1 vol	1.80
.	The above form an enlargement of the original work, "Mathematical Instruments" (No. 32).	
171	Engineering Drawing, by John Maxton	1.40
172.	Mining Tools, by William Morgans	1.00
172*.	Plates to ditto, 235 Engravings, 4to	1.80
173.	Physical Geology, by Portlock and Tate	.80
174.	Historical Geology, by Ralph Tate, F. G. S.	1.00
173, 174.	Geology, Portlock and Tate, 1 vol	1.80
175.	Builder's and Contractor's Price Book	
176.	The Metallurgy of Iron, by H. Bauerman	2.00
177.	Culture of Fruit Trees, by Du Breuil	1.40
178.	Practical Plane Geometry, by J. F. Heather	.80
180.	Coal and Coal Mining, by W. W. Smyth	1.40
181.	Painting (Fine Art), by Gullick and Timbs	2.00
182.	Carpentry and Joinery, by Tredgold and Tarn	1.40
182*.	Atlas of 35 plates to the above	2.40
183.	Animal Physics, by Dr. Lardner. Part I.	1.60
184.	Ditto. Part II.	1.20
183, 184.	Ditto. In 1 Vol. Cloth boards	3.00
185.	The Complete Measurer, by Richard Horton	1.60
186.	Grammar of Coloring, by Field, Enlarged by Ellis A. Davidson, with colored plates	1.20

SCIENTIFIC PUBLICATIONS.

No.		PRICE.
187.	Hints to Young Architects, by G. Wightwick, Enlarged by G. H. Guillaume	$1.40
188.	House Painting, &c., by Ellis A. Davidson	2.00
189.	Practical Bricklaying, by Adam Hammond	.60
190.	Steam and the Steam Engine, by D. K. Clark	1.40
191.	Plumbing, House Drainage and Ventilation, by W. P. Buchan. Fifth Edition, Enlarged	1.40
192.	Timber Importers' and Builders' Guide, by Grandy	.80
193.	Field Fortification, by Major W. W. Knollys	1.20
194.	House Manager, by an Old Housekeeper	1.40
194, 112, 112*.	House Book (The). Three vols. in one, half-bound	2.40
196.	Compound Interest and Annuities, by F. Thoman	1.60
197.	Roads and Streets, by Law and Clark	1.80
198.	The Sheep, by W. C. Spooner	1.40
199.	The Compendius Calculator, by D. O'Gorman, revised by C. Norris	1.00
200.	Fuel, by C. W. Williams and D. K. Clark	1.40
201.	Kitchen Gardening made Easy, by Glenny	.60
202.	Locomotive Engines, by Dempsey, with additions by D. K. Clark	1.20
203.	Sanitary Work, by Charles Slagg	1.20
204.	Mathematical and Nautical Tables, with Treatise on Logarithms, by Law and Young	1.60
204*.	Logarithms, Treatise on, with Tables, by Law, from the above	1.20
204 & 55.	Practical Navigation, in 1 vol., half-bound	2.80
205.	Letter Painting Made Easy, by J. G. Badenoch	.60
206.	A Book on Building, by Sir Edmund Beckett	1.80
207.	Farm Management, by R. Scott Burn	1.00
208.	Landed Estates Management, by R. Scott Burn	1.00
207, 208.	Farm and Landed Estates Management, by R. Scott Burn, in 1 vol., half-bound	2.40
209.	The Tree Planter and Plant Propagator: A Practical Manual, by Samuel Wood	.80
210.	The Tree Pruner, by Samuel Wood	.60
209, 210.	The Tree Planter, Propagator, and Pruner, by Samuel Wood. In 1 vol., half-bound	1.40
211.	The Boilermaker's Assistant, by Courtney	.80
212.	The Construction of Gasworks, by S. Hughes. Seventh Edition by William Richards	2.20
213.	Pioneer Engineering, by Edward Dobson, C. E.	1.80
214.	Slate and Slate Quarrying, by D. C. Davies	1.20
215.	The Goldsmith's Handbook, by G. E. Gee	1.20
216.	Materials and Construction, by F. Campin	1.20
217.	Sewing Machinery, by J. W. Urquhart, C. E.	.80
218.	Hay and Straw Measurer, by John Steele	.80

No.		PRICE.
219.	Civil Engineering, by Law and Burnell, with Recent Practice, by D. K. Clarke, M. I. C. E.	$2.60
221.	Measures, Weights, and Moneys of All Nations, by W. S. B. Woolhouse. New Edition	1.00
222.	Suburban Farming, by Prof. Donaldson	
223.	Mechanical Engineering, by F. Campin, C. E.	1.00
224.	Coach Building, by Jas. W. Burgess	1.00
225.	The Silversmith's Handbook, by G. E. Gee	1.20
215, 225.	The Goldsmith's and Silversmith's Complete Handbook, by Gee. half-bound	2.80
226.	The Joints used by Builders, by J. W. Christy	1.20
227.	Mathematics as applied to the Constructive Arts, by F. Campin, C. E.	1.20
228.	The Construction of Roofs, by E. W. Tarn	.60
229.	Elementary Decoration, by J. W. Facey	.80
230.	Hand Railing by Geo. Collings	1.00
231.	Grafting and Buding, by C. Baltet	1.00
232.	Cottage Gardening, by E. Hobday	.60
233.	Garden Receipts. Edited by C. W. Quin	.60
234.	Market and Kitchen Gardening, by C. W. Shaw	1.20
235.	Practical Organ-Building, by Dickson	1.00
236.	Details of Machinery, by F. Campin, C. E.	1.20
237.	The Smithy and Forge, by Crane. 2d Edition	1.00
238.	Sheet Metal Workers' Guide, by Crane	.60
239.	Draining and Embanking, by Prof. Scott	.60
240.	Irrigation and Water Supply, by Prof. Scott	.60
241.	Farm Roads, Fences and Gates, by Prof. Scott	.60
242.	Farm Buildings, by Prof. Scott	.80
243.	Barn Implements and Machines, by Prof. Scott	.80
244.	Field Implements and Machines, by Pros. Scott	.80
245.	Agricultural Surveying, by Prof. Scott	.60
239 to 245.	The 7 vols. in 1, half-bound	4.80
246.	Dictionary of Painters, by P. Daryl	1.00
247.	Building Estates, by Fowler Maitland	.80
248.	Portland Cement for Users, by Faija	.80
249.	The Hall-Marking of Jewelry, by Gee	1.20
250.	Meat Production, by John Ewart	1.00
251.	Steam and Machinery Management, by M. Powis Bale, C. E.	1.00
252.	Brickwork, a Practical Treatise, by F. Walker. 2nd Edition, revised.	.60
23, 189 & 252.	The Practical Brick and Tile Book, in 1 volume, half-bound.	
253.	The Timber Merchant's Freight Book, by W. Richardson and M. P. Bale,	
254.	The Boilermaker's Ready Reckoner, by J. Courtney, revised by D. K. Clark	1.60
254 and 211	in one volume, half bound	2.80

No.		Price.
256.	Stationary Engine Driving, by Michael Reynolds	$1.40
257.	Practical House Decoration, by Facey	1.00
229, 257.	House Decoration, by Facey, in 1 volume, half-bound	2.00
258.	Circular Work in Carpentry, by Collings	1.00
259.	Gas-Fitting, by John Black	1.00
260.	Iron Bridges of Moderate Span, by Hamilton W. Pendred	.80
261.	Shoring, by Geo. H. Blagrove	.60
262.	Boot and Shoemaking, by J. B. Leno	.80
263.	Mechanical Dentistry, by C. Hunter	1.20
264.	Mining and Quarrying, by J. H. Collins	.60
265.	Practical Brick Cutting and Setting, by Adam Hammond	.60
23, 189, 265	in one volume, half bound	2.40
267.	The Science of Building, by E. W. Tarn	1.40
268.	The Drainage of Lands, Towns and Buildings, by G. D. Dempsey. Revised, with additions, by D. K. Clark. 2d ed	1.80
269.	Light; an Introduction to the Science of Optics, by E. W. Tarn	.60
270.	Wood Engraving, by W. N. Brown	.60
271.	Ventilation, by W. P. Buchan	1.40
272.	Roof Carpentry, by George Collings	.80
273.	The Practical Plasterer, by W. Kemp	.80
274.	Elementary Marine Engineering, by J. S. Brewer	.60
275.	Laundry Management	.80
276.	Cement, Pastes, Glues and Gums, by H. C. Standage	.80
277.	Fuels; Their Analysis and Valuation, by H. J. Phillips	.80
278.	Model Locomotive Engineer, Fireman, &c., by M. Reynolds	1.40
279.	Constructional Iron and Steel Work, by F. Campin	1.40
280.	Iron and Steel Bridges and Viaducts, by F. Campin	1.40
281.	French Polishing and Enamelling, by R. Bitmead	.60
282.	Electric Lighting, by A. A. C. Swinton	.60

3 2044 050 748 292

A

This book should be returned to the Library on or before the last date stamped below.

A fine of five cents a day is incurred by retaining it beyond the specified time.

Please return promptly.

DUE FEB 28 1916

~~DUE MAY -2 '38~~

DUE MAR 29 1916

~~DUE DEC -8 '47~~

DUE NOV 8 1917

DUE DEC 7 1917

DUE DEC 27 1917

DUE FEB 12 1918

DUE DEC 30 1920

DUE DEC -4 1924

DUE FEB 12 1925

DUE JAN 12 1929

3 2044 050 748 292